ENGINEERING LIBRARY FEB 6 1948

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD ST., STRAND, LONDON, W.C.2

VOL. 165—No. 4277 *Registered at the General Post Office as a Newspaper* *LONDON: FRIDAY, JANUARY 16, 1948.* PRICE 1s. 6d. POSTAGE {INLAND 2½d. FOREIGN 3d.

Air Receivers Buoys, Road Wagons, Tanks **TANKS** Hoppers, Chimneys, Ducting.
EVERYTHING FROM MILD STEEL PLATE
JOHN BELLAMY
EAST 1892 LIMITED MILLWALL, E.14 EST. 1860 1216

EDWARDS
For 'BESCO' SHEET METAL WORKING MACHINERY
Also MACHINE TOOLS
F. J. EDWARDS LTD.
359-361, EUSTON ROAD, LONDON, N.W.1
Telephone: Euston 4681-3771

METAL SLITTING SAWS
GROUND FLAT STOCK
WILLIAM WARD & SON (SHEFFIELD), LTD., CENTENARY WORKS, WOODSEATS ROAD, SHEFFIELD 5388

J. & E. HALL
REFRIGERATION
FOR LAND & MARINE PURPOSES
LIFTS AND ESCALATORS
J. & E. HALL, LTD., ENGINEERS, DARTFORD KENT.
Telephone Dartford 3456
London Office: 10, ST. SWITHIN'S LANE, E.C.4.
Telephone: MANSION HOUSE 9811
5492

SPENCER-BONECOURT
Patent Waste Heat Boilers
34/36, Farringdon Street, E.C.4. 4971

BIBBY COUPLINGS
5200

SQUARE HEAD SETSCREWS
BRIGHT AND HARDENED TYPES
H. FORDSMITH LTD.,
Hadfield Street Works, Cornbrook, MANCHESTER, 16.
TRAfford Park 1615 and 1616 5589

LOCOMOTIVES
STEAM OR DIESEL
HUDSWELL CLARKE & Co.Ltd.
RAILWAY FOUNDRY, LEEDS
London Office: 46, Victoria St., S.W.1.
Telephone: Victoria 1133 8559

SECTIONAL PRESSED STEEL TANKS
also
RIVETED and WELDED PLATEWORK, STORAGE TANKS, BUOYS CHIMNEYS, BUNKERS, HOPPERS, Etc.
BROWN, LENOX & CO. (LONDON), LIMITED.
Contractors to the Admiralty since 1808
MILLWALL LONDON E.14.
Telephone: East 3261/2. 4900

YARROW
& CO., LTD.
GLASGOW
SHIPBUILDERS
MARINE ENGINEERS 4893
LAND AND MARINE BOILER MAKERS

BROTHERHOOD
AIR AND GAS
COMPRESSORS
PETER BROTHERHOOD LTD.
PETERBOROUGH. 6938

TATTERSALL
& SONS LTD.
BRICK CHIMNEYS, STOVES, BLAST FURNACE LININGS.
EST. 1898. 137, SOUTHFIELD RD. MIDDLESBROUGH

PUMPS.. Tel.
London Holborn 4271 (5 lines) Newark 601-2-3-4
Manchester Blackfriars 3810 Newcastle 22333
Birmingham Midland 5310 Glasgow Douglas 1974
Liverpool Central 1877
WORTHINGTON - SIMPSON

FORGINGS.
WALTER SOMERS, LTD.,
HALES OWEN 7115

DREDGERS
OF ALL TYPES
FERGUSON BROS. (Port-Glasgow) LTD.
PORT-GLASGOW 5290

BARRY CONVEYORS
BARRY, HENRY & COOK, LTD.
ABERDEEN 5586

ELECTRIC
SALINOMETERS
FEED WATER FILTERS, VALVE RESEATERS.
W. CROCKATT & SONS, LTD.
DARNLEY STREET - GLASGOW 5049

FRASER BOILERS
FOR
HIGH PRESSURE TESTING OF VALVES, ETC.
FRASER & FRASER, LTD.,
Bromley-by-Bow, London, E.3. 5101

HEATING & VENTILATION
ROSSER & RUSSELL LTD.
HEATING AND VENTILATING SPECIALISTS
30/31, Conduit Street, London, W.1. Tel. No. Mayfair 9141
Bank Low Mills, Marsh Lane, Leeds, 9 Tel. No. Leeds 20911
5480

RAPIER
EXCAVATORS
and
WALKING DRAGLINES
RANSOMES & RAPIER LTD. Ipswich - England 5199

CRADLEY BOILERS
CRADLEY BOILERS CO. LTD., CRADLEY HEATH, STAFFS. 5585

MUREX
Electrodes
MUREX WELDING PROCESSES LTD.
WALTHAM CROSS, HERTS. 5214
Telephone: Waltham Cross 3636

PATTERNS
WOOD & METAL
B. LEVY & CO.
1, OSBERT STREET, VINCENT SQUARE, S.W.1
Telephone: VICtoria 1073 & 7486.

CRANES
GEORGE RUSSELL & CO., LTD.
Motherwell. 4876

VISCO
AIR FILTERS
DUST COLLECTORS
COOLING TOWERS 5292
THE VISCO ENGINEERING CO., LTD.
Stafford Road, Croydon.
Phone: CROydon 4181/4 & 2471

SPECIAL MACHINERY MADE TO ORDER
'Phone: EUSTON 3176 (4 lines).
GEORGE WAILES & CO. LTD.
382-8 EUSTON RD., LONDON, N.W.1.
Specialists since 1855

WISEMAN
REDUCTION GEARS
ALFRED WISEMAN & CO. Ltd.
GLOVER STREET, BIRMINGHAM, 9.

RESEARCH
ENGINEERS LTD
FOR
PROTOTYPES
FOR DETAILS
SEE FIRST CLASSIFIED PAGE

MOSS GEARS ARE BETTER
GEARS
THE MOSS GEAR CO., LTD.
Crown Works, Tyburn, Birmingham. 4945

COOPER
SPLIT
ROLLER BEARINGS
KING'S LYNN 5381 NORFOLK

WAGONS
HURST NELSON & CO., LTD.,
MOTHERWELL

TAYLOR AND CHALLEN POWER PRESSES
TAYLOR AND CHALLEN LIMITED 2858
DERWENT WORKS, BIRMINGHAM, 19

STEPHENS V-BELT DRIVES
Send for copy of V-Belt Drive Data Chart
STEPHENS BELTING CO. LTD
V-DRIVE WORKS,
SNOW HILL, BIRMINGHAM, 4

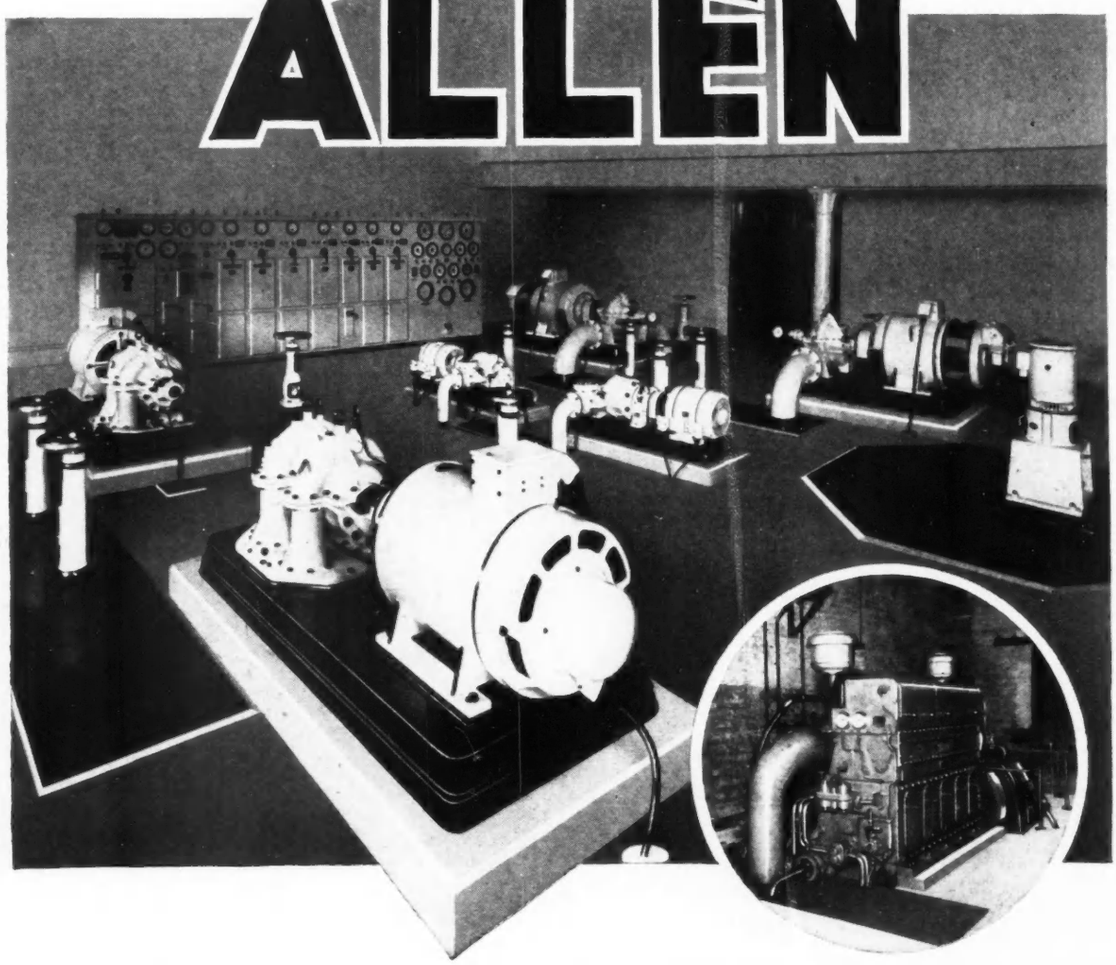
ALLDAYS & ONIONS
5353 BIRMINGHAM LTD.
BLOWERS ROOTS AND ROTARY

WEIR
DE-AERATORS
G. & J. WEIR LTD. GLASGOW.

SAMUEL **PLATT** LIMITED
King's Hill Foundry, Wednesbury, Staffs
UPSET FORGING MACHINES
DROP STAMPS, PRESSES, DRAWBENCHES 4599

PATERSON
SPECIALISTS
IN ALL FORMS OF
WATER TREATMENT
FOR
MUNICIPAL
AND
INDUSTRIAL
PURPOSES 5533
83, KINGSWAY, LONDON

ALLEN



WATERWORKS PUMPING PLANT

THE illustration shows the interior of the Ravensthorpe Pumping Station of the Northampton Corporation. This installation of ALLEN motor-driven pumps, comprises :—

A vertical 2-stage turbine type well pump (125 g.p.m., 80 feet head) ; two single-stage double-suction pumps (in background) supplying low-pressure mains (1215 g.p.m., 167 feet head, 1750 r.p.m., or 695 g.p.m., 70 feet head, 1130 r.p.m.) or any intermediate duty obtainable over this range ; two 2-stage double-suction pumps (in foreground) serving high-pressure mains (1215 g.p.m., 175 feet head) ; two 4-stage pumps (in centre) for supplying rural districts (100 g.p.m., 400 feet head).

The electrical switchboard incorporates the metering panel, pressure gauges and recorders for the hydraulic system. In an adjacent building is a 150-kW Allen Diesel engine-generating set for stand-by duty (inset picture).

This station which originally housed steam-driven plant, is a good example of how existing buildings can be used to accommodate machinery of entirely different character.

W. H. ALLEN, SONS & Co. LTD.

BEDFORD ENGLAND

A735.47

INTERMESHING NON-CIRCULAR ALGEBRAIC GEARS.

By COLONEL CLIVE TEMPERLEY, O.B.E., M.C., B.Sc.

THE characteristic features of a pair of non-circular gears are, firstly, that the gear ratio between them varies continuously as the gears turn and, secondly, that the angular displacement of one gear is not a simple multiple of the angular displacement of the other, but some algebraic or other function of it.

The fact that the gear-ratio is variable has been put to practical use for providing intermittent or variable drive for machinery, the best-known examples being scroll gears and the so-called elliptical gears. The fact that the displacements of a pair of non-circular gears are connected by an algebraic or other function has only been used, as far as the writer knows, in range-finders, although gears which operate in accordance with an algebraic function should be of value in designing calculating and computing machines, meters, automatic-control mechanisms, gun predictors, and the like. The difficulty seems to have been the absence of any simple method of designing intermeshing non-circular gears which operate in accordance with any wide variety of equations.

In most standard works on mechanics there is some reference to non-circular gears. The reference is usually brief and no standard work appears to give a practical method of design. The most lengthy treatment is in Robinson's *Principles of Mechanics*. Robinson comes to the conclusion that there are only five simple non-circular gears which work properly, namely, "log" gears, elliptical gears, parabolic gears, hyperbolic gears and what he calls "transformed wheels." He is wrong; there are large numbers of relatively simple gears other than those he names. Robinson's "transformed wheels" are pairs of non-circular gears which are generated from known intermeshing circular or non-circular gears by a graphic method which depends on the measurement of lengths along the arc. The value of the method for any practical purpose seems doubtful.

A search of British Patents reveals only two dealing with non-circular gears, both designed to give logarithmic conversion. Legros (247,314 of 1926) describes, illustrates and gives polar co-ordinates for pitch-lines of a form "resembling logarithmic spirals." He says that "no mathematical or simple graphical method of generating (correct) curves are known to me at present." In fact, it is not difficult to show that the curves described by him neither mesh properly nor give true conversion to logarithms. Wendling (340,013 of 1930) describes the kind of curve he wants and adds that they would have "Practically the same shape" as his illustration, which shows two identical intermeshing curves. Identical curves cannot give conversion to logarithms.

The first real effort to deal with the problem seems to be a paper by Goldber before the American Society of Mechanical Engineers in 1939. Goldber considers the mathematical implications of non-circular gears and arrives at the general mathematical expression for the pitch-lines; but he stops at this promising point and branches off into a graphic method of designing gears, which he calls "Rollcurves." In brief, he draws a graph of a desired motion which is to be imparted to a driven shaft, and develops a graphical method of designing a pair of intermeshing non-circular gears which will convert a uniform rotation into the desired motion. The method is based on measuring the area under the graph by Simpson's Rule, etc. He admits that errors occur because of the "inability of the author to integrate accurately for lengths of arc."

Here, it seems, is the root of the trouble. The proper intermeshing of non-circular gears depends on the lengths along the arcs of the two gears being identical between any two points of contact; and it is frequently difficult and sometimes impossible to measure lengths along the arc algebraically because this involves the solution of differential equations of quadratic degree. These authorities and patentees, however, seem to have overlooked the fact that measurement along the arc can be avoided altogether if the general theory of intermeshing non-circular gears is fully developed.

If two non-circular curves turn about fixed axes in rolling contact, the touching points on the curves must be moving in the same direction at the moment of contact. As each of these points must also be moving at right angles to the radius joining it to the axis about which it is turning, their movement in the same direction is only possible when these radii are in line. Accordingly, the point of contact must lie on the line joining the axes.

Consider two such curves, I and II, in Fig. 1, which touch at the point P and turn about the axes O_1 and O_2. Let the polar equations of the two curves be functions of $r\theta$, and $s\phi$, respectively, and the distance between the axes be D. Let the points P_1 and P_2 be the points which will come in contact after the curves have turned through further small angles $d\theta$ and $d\phi$, respectively. Then the conditions for true rolling contact are that the curves shall have a common tangent at P, and that arc $P P_1$ = arc $P P_2$.

The tangent of curve I at P makes an angle of $\tan^{-1} r \frac{d\theta}{dr}$ with the line joining the axes and the similar angle for curve II is $\tan^{-1} s \frac{d\phi}{ds}$. These tangents must be equal. Therefore,

$$r \frac{d\theta}{dr} = s \frac{d\phi}{ds};$$

but, as the axes are fixed

$$r + s = D \text{ (constant)}, \quad . \quad (1)$$

or

$$\frac{dr}{ds} = 1,$$

or

$$dr = ds. \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Hence the first condition for rolling contact is :—

$$\frac{d\phi}{d\theta} = \frac{r}{s}. \quad . \quad . \quad . \quad . \quad (3)$$

Next, in the limit,

$$\text{Arc } P P_1 = \sqrt{(r\,d\theta)^2 + (d\,r)^2},$$

and

$$\text{Arc } P P_2 = \sqrt{(s\,d\phi)^2 + (ds)^2}.$$

Equating these, we have :

$$(r\,d\theta)^2 + (dr)^2 = (s\,d\phi)^2 + (ds)^2;$$

Fig. 1.

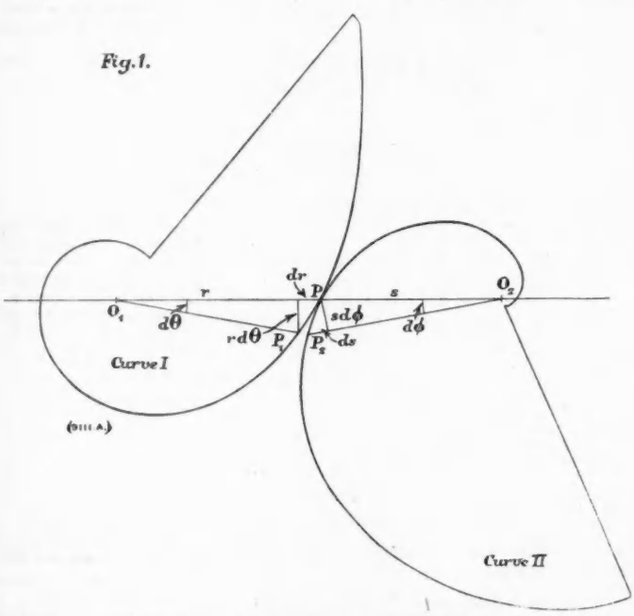
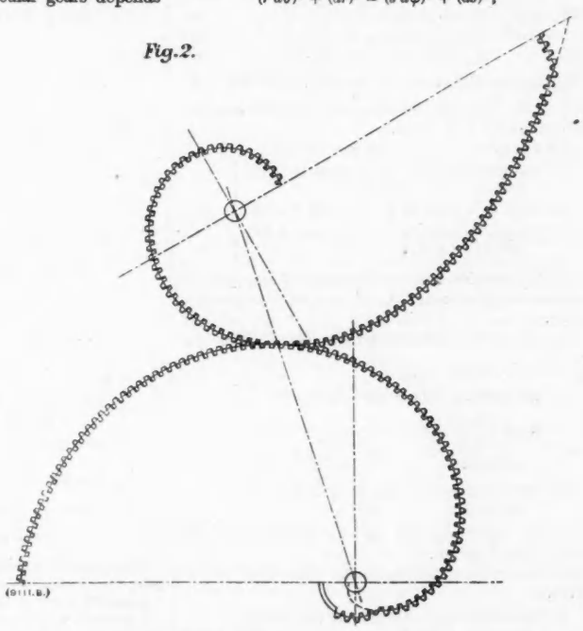


Fig. 2.



but, by (2),

$$dr = ds.$$

Hence, the second condition reduces to

$$(rd\theta)^2 = (s\,d\phi)^2$$

or, in the limit,

$$\frac{d\phi}{d\theta} = \pm\frac{r}{s},$$

which is satisfied by the first condition, equation (3). The sole condition, therefore, for rolling contact between two curves turning about fixed axes is that

$$\frac{d\phi}{d\theta} = \frac{r}{s}. \quad . \quad . \quad . \quad . \quad (4)$$

But by (1)

$$r + s = D \quad \text{or} \quad s = D - r;$$

hence by (4)

$$\frac{d\phi}{d\theta} = \frac{r}{D - r},$$

or

$$(D - r)\frac{d\phi}{d\theta} = r,$$

or

$$r\left(1 + \frac{d\phi}{d\theta}\right) = D\frac{d\phi}{d\theta},$$

or

$$r = \frac{D\dfrac{d\phi}{d\theta}}{1 + \dfrac{d\phi}{d\theta}},$$

or

$$r = \frac{D}{\frac{1}{\frac{d\phi}{d\theta}} + 1}.$$

Similarly,

$$s = \frac{D}{\frac{1}{\frac{d\theta}{d\phi}} + 1} \quad . \quad . \quad . \quad . \quad (6)$$

In formulæ (5) and (6), $\frac{1}{\frac{d\phi}{d\theta}}$ is a function of θ and $\frac{1}{\frac{d\theta}{d\phi}}$ is a function of ϕ. It is convenient to refer to these functions as the moduli, M_θ and M_ϕ, of the polar equation of the pitch lines. Hence, if the relationship between the angular displacements of a pair of intermeshing non-circular gears is $\phi = F(\theta)$,

$$\text{modulus } M_\theta = \frac{1}{\frac{d\phi}{d\theta}}, \text{ modulus } M_\phi = \frac{1}{\frac{d\theta}{d\phi}}, \quad . \quad (7)$$

and

$$r = \frac{1}{M_\theta + 1}, \; s = \frac{1}{M_\phi + 1}. \quad . \quad . \quad (8)$$

RULES FOR CALCULATING PITCH-LINE FORMULÆ.

(*a*) If the function between the angular displacements, ϕ and θ, is given.

Let the given function be $\phi = F(\theta)$.

(i) The modulus M_θ is the reciprocal of the first derivative of $F(\theta)$
(ii) Solve $\phi = F(\theta)$ for θ – so that $\theta = J(\phi)$
(iii) The modulus M_ϕ is the reciprocal of first derivative of $J(\phi)$. (9)

(*b*) If the function between the gear-ratio, g, and the angular displacement, θ, of one of the gears is given.

Let the given function be $g = G(\theta)$. But $g = \frac{d\phi}{d\theta} = G(\theta)$, hence

(i) The modulus M_θ is reciprocal of $G(\theta)$
(ii) Solve $\frac{d\phi}{d\theta} = G(\theta)$, or $\phi = \int G(\theta) d\theta$ for θ, so that $\theta = J(\phi)$
(iii) The modulus M_ϕ is the reciprocal of the first derivative of $J(\phi)$. (10)

(*c*) If the polar equation of the pitch line of one of the gears is given.

Let the polar equation of the pitch line be $r = H(\theta)$.

(i) Re-write the polar equation of the known pitch line in the form :—

$$r = H(\theta) = \frac{1}{\frac{1 - H(\theta)}{H(\theta)} + 1}$$

(ii) Solve $\frac{d\phi}{d\theta} = \frac{1 - H(\theta)}{H(\theta)}$ or

$$\phi = \int \frac{1 - H(\theta)}{H(\theta)} d\theta \text{ for } \theta,$$

so that $\theta = J(\phi)$

(iii) The modulus $M\phi$ of the equation of the unknown pitch line which will mesh with the known pitch line is the reciprocal of the first derivative of $J(\phi)$. (11)

It should be noted, in all these calculations, that the pitch line for the driven gear, $s = \frac{1}{M_\phi + 1}$ can be calculated, without knowing M_ϕ, from $\phi = F(\theta)$, $r = \frac{1}{M_\theta + 1}$ and $s = D - r$; in fact, it will usually be easier to calculate the values of s and ϕ in this way. Hence the gears can be designed accurately, even when it is difficult or impossible to solve the equations which yield $\theta = J(\phi)$.

Intermeshing Non-Circular Algebraic gears designed in accordance with the above rules will be referred to below as "Inca" gears.

For mechanical reasons, r and s must not change sign between the desired limits of θ and ϕ; otherwise, the pitch line would pass through the origin and the gear ratio would pass through an infinite value. In other words, r and s must always each be less than the distance between the axes, D. It follows, from equation (8), that M_θ and M_ϕ must have positive real values between the desired limits. As the signs of $\frac{d\phi}{d\theta}$ and $\frac{d\theta}{d\phi}$ can be reversed merely by reversing the sign of ϕ (that is, by calibrating one of the gears in the opposite direction), this condition amounts to the moduli not changing sign between the limits. In addition, unless the functions concerned are of a suitable periodic nature, or other special mechanical arrangements are made, the rotation of the gears will be limited to 360 deg.

The conditions which have to be met in designing simple intermeshing non-circular gears can be summarised, therefore, as follows, firstly, the moduli M_θ and M_ϕ must equal $\frac{1}{\frac{d\phi}{d\theta}}$ and $\frac{1}{\frac{d\theta}{d\phi}}$ respectively; secondly, the moduli must not change signs between the desired limits of θ and ϕ and the sign (that is the direction of calibration) of ϕ must be chosen so that the moduli are positive; and, thirdly, unless θ is a suitable periodic function of ϕ, θ and ϕ must both be less than 360 deg. between the desired limits.

The first condition constitutes the rule by which the formulæ for gears can be calculated so as to give true intermeshing. The second condition can be met, when necessary, by splitting up the desired relationship into two or more equations and using two or more pairs of Inca gears in sequence or coupled through a differential link. The third condition is met by introducing suitable parameters into the equations and calibrating the mechanism accordingly. In this way, the range of the mechanism can be adjusted to any desired value.

The pitch line formulæ given above enable the mathematical operation corresponding to an equation in two variables to be effected by means of a pair of Inca gears on fixed axes. Where the desired equation has three or more variables, the operation may be effected by linking together the necessary number of pairs through any of the mechanisms which effect the addition or subtraction of the rotations of two shafts, such as a "differential" gear. If the equation involves the multiplication of functions of two independent variables, then the pitch lines are designed to give directly the logarithm of each function, the logarithms are added by a "differential" link, and the resultant sum is reconverted (if necessary) to a natural basis by a third pair of non-circular gears.

As examples of pitch-line formulæ, consider first the simple multiplication or division of two independent variables. This can be done readily if the independent variables effect the rotation of two shafts and the rotations can be converted mechanically into the rotations of a second pair of shafts equal to the logarithms of the rotations of the first shafts. These rotations are then (as described above) added or subtracted by a "differential" link and the sum

NON-CIRCULAR GEARS.

TABLE I.—REPRESENTATIVE MODULI OF PITCH-LINE EQUATIONS FOR INCA GEARS.

No.	Desired Relationship. Between θ and ϕ.	Between ϕ and θ.	Moduli. M_I.	M_{II}.	Remarks.
Col. 1	Col. 2.	Col. 3.	Col. 4.	Col. 5.	Col. 6.
1	$\phi = \theta^n$	$\theta = \phi^{\frac{1}{n}}$ ...	$\frac{1}{n}\theta^{1-n}$	$n\phi^{\frac{(n-1)}{n}}$	—
2	$\phi = a_n \theta^n + a_{n-1}\theta^{n-1} \ldots a_0$	—	$\left[n a_n \theta^{n-1} + (n-1) a_{(n-1)} \theta^{n-2} \ldots a_1\right]^{-1}$	—	s and ϕ may be calculated from Cols. (2) and (4).
3	$\phi = K^\theta$	$\theta = \frac{\log \phi}{\log K}$	$\frac{1}{K^\theta \log K}$	$\phi \log K$	—
4	$\phi = \log \theta$	$\theta = e^\phi$ ...	θ	$e^{-\theta}$	By adjusting parameters, desired relationships can be expressed in logarithms to the base 10.
5	$\phi = \log \log \theta$	$\theta = e^{e^\phi}$	$\theta \log \theta$	$e^{-e^\phi} e^{-\phi}$	
6	$\phi = \sin \theta$	$\theta = \sin^{-1}\phi$	—	—	$s_1 \phi_1$ and $s_2 \phi_2$ to be calculated from Cols. (2) and (4).
	Pair I $\phi_1 = a\theta + \sin\theta$	—	$\frac{1}{[a + \cos\theta]}$	—	ϕ_2 to be subtracted from ϕ_1 by differential link to give ϕ.
	Pair II $\phi_2 = a\theta$ $a > 1$	—	Circular gears with gear ratio a	—	Similar equations exist for $\phi = \cos\theta$.
7	$\phi = \sin^n \theta \quad n > 1$ ...	$\theta = \sin^{-1}\phi^{\frac{1}{n}}$	—	—	As for No. 6.
	Pair I $\phi_1 = a n \theta + \sin^n \theta$	—	$\frac{1}{[a n + n \sin^{n-1}\theta \cos\theta]}$	—	
	Pair II $\phi = a n \theta$ $a n > 1$	—	Circular gears with gear ratio $a n$	—	
8	$\phi = F_1(\theta_1) \times F_2(\theta_2)$...	—	—	—	$s_1 \phi_1$ and $s_2 \phi_2$ may be calculated from Cols. (2) and (4).
	Pair I $\phi_1 = \log F_1(\theta_1)$	—	$\frac{F_1 \theta_1}{F_1' \theta_1}$	—	ϕ_2 to be added to ϕ_1 by differential link to give θ_2.
	Pair II $\phi_2 = \log F_2(\theta_2)$	—	$\frac{F_2 \theta_2}{F_2' \theta_2}$	—	Pair III then gives ϕ.
	Pair III $\phi = e^{\theta_3}$ ...	—	e^{θ_3}	ϕ	Similar arrangement applies to $\phi = F_1\theta_1 \div F_2\theta_2$.
9	$\phi = F_1(\theta_1)^{F_2(\theta_2)}$ ...	—	—	—	As for No. 8.
	Pair I $\phi_1 = \log \log F(\theta_1)$	—	$\frac{F_1 \theta \log F_1 \theta_1}{F_1' \theta_1}$	—	
	Pair II $\phi_2 = \log F(\theta_2)$	—	$\frac{F_2 \theta_2}{F_2' \theta_2}$	—	
	Pair III $\phi = e^{e^{\theta_3}}$ ...	—	$e^{-e^{\theta_3}} e^{-\theta_3}$	$\phi \log \phi$	

The moduli M_I and M_{II} are the function of θ and ϕ in the pitch-line polar equations $r = \frac{D}{M_I + 1}$ and $s = \frac{D}{M_{II} + 1}$.

The necessary parameters can be inserted in the equations by putting $\phi = a\phi' + b$ and $\theta = c\theta' + f$, and by using the general formulæ for parameters.

Logarithms are to the base e.

F stands for "function"; F', for the first derivative of the function.

NON-CIRCULAR GEARS.

Fig. 3.

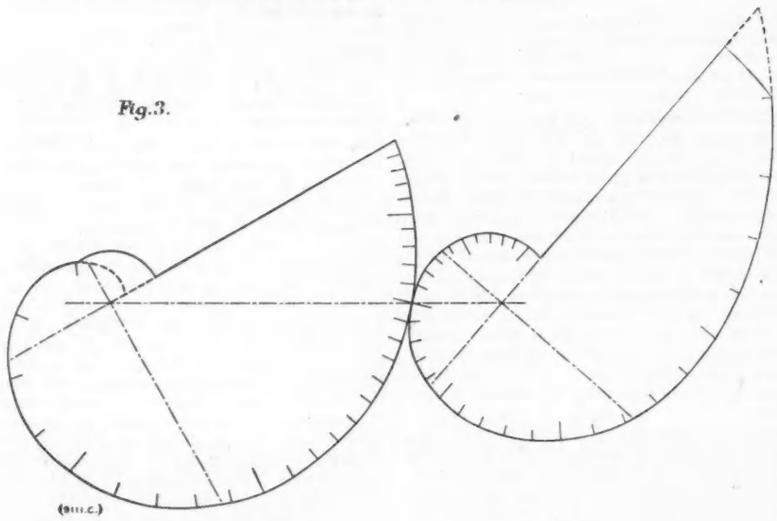
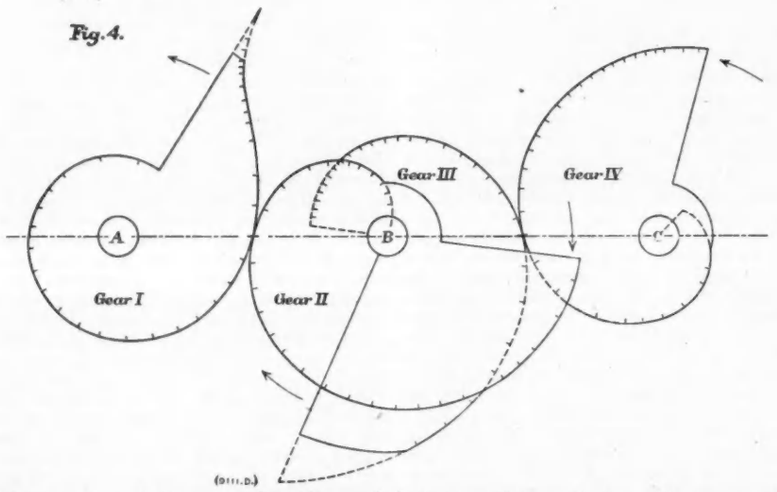


Fig. 4.



or difference reconverted to a natural rotation equal to the product or quotient of the independent variables. The mathematical operation of converting a natural rotation into its logarithm and of reconverting a logarithm to a natural number can be written :

$$\phi = K \log \theta, \text{ and } \theta = e^{\frac{\phi}{K}};$$

the logarithm is to the base e.

Differentiating with respect to each variable, we have :

$$\frac{d\phi}{d\theta} = \frac{K}{\theta}, \text{ or } M_\theta = \frac{\theta}{K},$$

$$\frac{d\theta}{d\phi} = \frac{1}{K} e^{\frac{\phi}{K}}, \text{ or } M_\phi = K e^{-\frac{\phi}{K}}.$$

Hence, logarithmic conversion can be effected by Inca gears with pitch lines conforming to the following formulæ :

$$\left.\begin{aligned} r &= \frac{D}{\frac{\theta}{K} + 1} \\ s &= \frac{D}{K e^{-\frac{\phi}{K}} + 1} \end{aligned}\right\} \quad . \quad . \quad . \quad (12)$$

Reconversion can be effected by using the gears in the reverse order. Inca gears of this nature, with a range of 60 : 1, are illustrated in Fig. 2, on page 49 ; as designed, they have involute teeth with a pitch of 0·125, an addendum of 0·03975, and a dedendum of 0·046.

By means of the rules given above, pitch-line formulæ for a great number of other mathematical operations in two variables can be easily arrived at ; for instance, if the required operation corresponds to the equation $\phi = \theta^n$, the moduli are clearly $\frac{1}{n}\theta^{1-n}$ and $n\phi^{\frac{n-1}{n}}$.

A more complicated example is provided by the operation $\phi = \log \log \theta$, which is needed for the solution of compound interest problems. It will be seen that this operation can be carried out mechanically by Inca gears with pitch lines as follows :

$$\left.\begin{aligned} r &= \frac{D}{\theta \log \theta + 1} \\ s &= \frac{D}{e^{-e^{\phi}} e^{-\phi} + 1} \end{aligned}\right\} \quad . \quad . \quad (13)$$

Examples of such pitch lines for log-log gears are illustrated in Fig. 3, on this page. A list of moduli for operations conforming to a number of other algebraic expressions is given in Table I, opposite.

To illustrate the re-arrangement of equations to meet the condition that moduli must not change sign, consider the operation corresponding to the equation : $\phi = \sin \theta$ between the limits $\theta = 0$ and $\theta = 2\pi$. Then, $\frac{d\phi}{d\theta} = \cos \theta$, and $M_\phi = \sec \theta$. Hence, in this form, M_ϕ will change sign twice between limits, and the second condition is contravened. It is necessary, therefore, to divide the operation into two :

Operation (1).

$$\phi_1 = a\theta + \sin \theta \quad (a > 1);$$

$$\frac{d\phi}{d\theta} = a + \cos \theta; \text{ and}$$

$$M_\phi = \frac{1}{a + \cos \theta}. \quad \text{(hence } M_\phi > 0 \text{ as required).}$$

Operation (2).

$$\phi_2 = a\theta;$$

$$\frac{d\phi}{d\theta} = a; \text{ and}$$

$$M_\phi = \frac{1}{a}.$$

The Inca gears which effect operation (1) meet the second condition, while operation (2) consists merely of a pair of circular gears with gear ratio a. If, then, the driving shafts of the non-circular and the circular gears be both turned by a common shaft through an angle θ, and the driven shafts be linked by a "differential" gear so that their rotations are subtracted, the epicyclic arm of the differential will rotate through an angle equal to sin θ, which is the desired result.

After (if necessary) re-arranging the equations in the above or a similar manner, the numerical value of the parameters to cover the required range of the independent variable can be arrived at directly by use of the following equations :

Let the desired relationship to which the gears are to give effect be $\phi' = F(\theta')$; let the upper limit of the range of θ' be θ'_H, and of ϕ' be ϕ'_H ; let the lower limit of the range of θ' be θ'_L and of ϕ' be ϕ'_L ; put $\phi' = a\phi + b$ and $\theta' = c\theta + f$, so that the required equation connecting the rotations of the gears becomes $a\phi + b = F(c\theta + f)$. Then, for the general case :

$$\left.\begin{aligned} a &= \frac{1}{2\pi}(\phi'_H - \phi'_L) \\ b &= \phi'_L \\ c &= \frac{1}{2\pi}(\theta'_H - \theta'_L) \\ d &= \theta'_L \end{aligned}\right\} \quad . \quad . \quad . \quad (17)$$

In the special case in which the relationship is logarithmic and the gear includes a section of circular arc, the parameters can be calculated from the following equations : Let the required relation be $\phi' = \log F(\theta')$; let $\phi' = a\phi + b$, and $\theta' = c\theta$; moreover, let w'_L equal the value of

$$\frac{dF(\theta')}{d\theta'} \times \frac{\theta'}{F(\theta')} \text{ when } \theta' = \theta'_L.$$

Then

$$\left.\begin{aligned} a &= \frac{1}{2\pi}\left[\phi'_H - \phi'_L + w'_L\right]; \\ b &= \phi'_L - w'_L; \text{ and} \\ c &= \frac{1}{2\pi}\theta'_H. \end{aligned}\right\} \quad . \quad (18)$$

In some cases it may be found that, near the limit of the range of the independent variable, the gear ratio between the Inca gears is very high and the consequent short radius of one or other of the gears may interfere with design. In such a case, it is usually possible to replace the pair of gears by two or more pairs working in series, in each of which the gear ratio has been reduced to tolerable size. For instance, the gear ratio between a pair of Inca gears giving logarithmic conversion is equal to $\frac{1}{\theta}$; the pair can be replaced, therefore, by n pairs linked in series, the gear ratio of each pair being $\frac{1}{\theta^{\frac{1}{n}}}$ to give the same final result. Pitch lines for two such pairs coupled in series to give logarithmic conversion are shown in Fig. 4, on this page ; the range ratio is 100 : 1.

If Inca gears are used for calculating or metering purposes, no great load is transmitted by the teeth and, to avoid backlash, the teeth should be as small as possible. If the gears are used for transmitting power, the teeth should be designed in the normal manner, having regard to the power to be transmitted, and the axes of the teeth can be at right angles to the pitch line. The movement between the gears is a true rolling contact and the teeth, as it were, have no means of knowing that they are turning about any axis other than the normal one. If there is no play in the bearings, the teeth are under normal stresses. There will, however, be a thrust between the bearings of greater or lesser degree, and the bearings may have to be designed specially to withstand this additional thrust and to avoid undue wear. When the normals to the

pitch lines pass fairly close to the axes, skew teeth can sometimes be designed to avoid the additional thrust altogether.

As the movement between Inca gears is a true rolling contact, the teeth usually lock together, so that the gears cannot become unmeshed, in spite of a rather striking appearance to the contrary.

In laying out the gear teeth for Inca gears, it is useful to be able to draw the normal to the pitch line at any point and to know the radius of curvature. Let the pitch-line formula be, in the notation of equation (8),

$$r = \frac{D}{M + 1},$$

let

$$\frac{dM}{d\theta} = M', \text{ and}$$

$$\frac{d^2M}{d\theta^2} = M''.$$

Then the angle between the normal and the radius vector is

$$\tan^{-1}\left(-\frac{r}{D}M'\right), \quad . \quad . \quad (19$$

and the radius of curvature R at this point is given by the equation:

$$\frac{R}{D} = \frac{r}{D}\frac{\left[1 + \frac{r^2}{D^2}(M')^2\right]^{\frac{3}{2}}}{1 + \frac{r}{D}M''}. \quad . \quad . \quad . \quad (20)$$

Graphical methods can frequently be devised from these equations to find the normal and the radius of curvature.

In designing gears for mechanical conversion to logarithms, when actual rotations are to be multiplied or divided, it is necessary to begin with a small leading section of circular gear which carries both gears from their zero setting to the lower limit of the range between which multiplication or division is required. At this point, a transition takes place to the non-circular gear conforming to the required pitch line (see Fig. 2, page 49). As the motion between the gears is a true rolling contact, no difficulty will arise at this transition except for the possible omission of the last one or two teeth of the circular gear to make way for the spiral teeth.

Inca gears can be designed to carry out mechanical operations corresponding to the numerical solution of a wide variety of algebraic equations, including raising to any power and extraction of roots (whether fractional or otherwise), conversion to logarithms and reconversion to natural numbers and the numerical solution of algebraic equations of any degree. By linking pairs of Inca gears through any of the well-known mechanisms which effect the addition or subtraction of rotations, equations in three or more variables can be solved numerically or applied mechanically. Inca gears enable such solutions or operations to be effected by directly intermeshing gears mounted on fixed axes, and they may, therefore, in some instances, provide a more sturdy, compact, reliable and accurate means than those at present employed. The method of design here described is not patented.

SPECIFICATIONS AND ANALYSES OF METALS AND ALLOYS.—Messrs. Murex Limited, Rainham, Essex, have published a new edition of their booklet entitled "Standard Specifications and Typical Analyses of Metals, Metallic Alloys and Carbides." The data given relate to ferro-tungsten, ferro-vanadium, ferro-molybdenum and other ferro-alloys, calcium molybdate, tungsten and molybdenum metal powders, manganese and chromium metal, and tungsten and other metallic carbides. Copies of the booklet may be obtained on application to Messrs. Murex Limited.

INDUSTRY IN SUSSEX.—The primary object of a booklet entitled "Industry in Sussex," which is being distributed by the Sussex Engineers and Manufacturers Association, Limited, 3, Marlborough-place, Brighton, 1, to H.M. Consuls, trade correspondents, Chambers of Commerce and buyers throughout the world is the obvious one of attracting a share of the increased export trade to the county. There may be some initial difficulty in doing this, since Sussex has been much publicised for other reasons. A perusal of the booklet, however, will show that the county has also much to offer from the engineering point of view, especially in the lighter branches of the industry; and it is hoped that the efforts of the Association to bring this fact to the notice of a wider circle will be successful.

LITERATURE.

Annual Report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington. The Director, Department of Terrestrial Magnetism, 5241, Broad Branch-road, Northwest, Washington 15, D.C., U.S.A. [Free].

THE present report, for the year 1945-46, is of special interest in that it covers the change-over from war to peace conditions. Between 1940 and 1946, expert assistance was given to such official bodies as the Army Signal Corps and the Engineer Board, the Navy Bureaux of Ordnance, Ships and Aeronautics, and the Office of Scientific Research and Development. This work absorbed at least 80 per cent. of the services of the regular staff, and employed a large group of temporary assistants. It included the setting up and operating of 15 ionospheric stations at such strategic points as Maui (Hawaii), Adak (Aleutian Islands) and Reykjavik (Iceland), compass improvement, work on methods of aircraft navigation, on the separation of uranium isotopes in connection with the atomic bomb project, the provision of radioactive tracers for biological research, the design of magnetic devices for locating mines, and the development of radio proximity fuses. Though these duties interrupted the regular scientific programme, it is pointed out that they have yielded by-products in improved techniques, applicable not only to geomagnetic surveys and experiments, but also for mass reductions, analyses and correlations of data by machine methods.

Despite war assignments, however, and the consequent curtailment of co-operative international activities, much of the normal programme of the department was carried out. The secular variations of the earth's field call for frequent determinations of the geomagnetic elements at many selected stations on land and at sea. Analysis of data from more than 10,000 stations enabled accurate isoporic charts (for example, charts of equal annual rate of change for magnetic declination, inclination and the horizontal, vertical, eastward, northward, and total components of the field) to be prepared for four epochs at intervals of ten years from 1912 to 1942. Attention was also given to the problem of magnetic surveys by air and to methods of improving the reliability of prediction of magnetic storms on the basis of their recurrence tendencies.

Observations of lightning and associated electrical phenomena were made in Mexico and studies in the rate of atmospheric ionisation were continued. Ionospheric investigations revealed the existence during magnetic storms of electronic clouds moving towards or away from the earth at velocities of the order of one to two km. per second between 800 km. and 400 km. above the earth. This discovery, of major importance in its bearing upon radio transmission, was made with the new "panoramic" ionosphere recorder, which enabled photographs of ionospheric activity to be secured at intervals ranging from 5 to 30 seconds.

Throughout the year the 60-in. Cyclotron was in steady operation and over 1,300 hours of target bombardment provided materials for biophysical researches, of which some details are given. The million-volt electrostatic generator was reconditioned and preliminary measurements were begun on the angular distribution of the disintegration protons from the O^{16} (d,p) reaction. Proposals for improving the pressure-type high-voltage generator are outlined and certain of them were put in hand.

The amount of routine observatory and field work carried out under the auspices of the department and in association with other departments is impressive. Summaries of selected data in tabular form show that the observations taken have not been allowed to accumulate without reduction. In preparation for the resumption of normal work members of the scientific staff were asked to prepare memoranda reviewing the work of their respective sections and suggesting future lines of development. Many of the projects suggested are listed in this report and promise to provide important material for future reports. Dr. J. A. Fleming, who joined the Department of Terrestrial Magnetism in 1904, retired as its director in June, 1946. In recognition of his distinguished work in geophysics, the Physical Society of London made their third biennial award of the Charles Chree Medal and Prize to him in December, 1945.

Fault Localising and Testing on Electric Mains. By F. CHARLES RAPHAEL, M.I.E.E., F.I.E.S., M.Cons.E., and CHARLES A. GROVER, M.I.E.E. Sir Isaac Pitman and Sons, Limited, Parker-street, London, W.C.2. [Price 20s. net.]

THE subject of this book was dealt with by Mr. Raphael in an earlier work entitled *Localization of Faults in Electric Light and Power Mains, with Chapters on Insulation Testing*, the third edition of which, published in 1916, has long been out of print. Since that time, electricity transmission and distribution have developed, both in application and technical methods, to such an extent that it has seemed desirable to supersede the earlier volume by a new treatise covering the whole field, in which the changes in the technique of testing and locating faults, which have been developed *pari passu* with the increase in transmission voltages, could be given the attention they deserve. A specific example of methods of relatively recent introduction is furnished by the use of thermionic valves for the purpose of applying high-voltage direct-current pressure tests. Developments of this kind, which have followed the gradual rise in the voltages normally in use, have not superseded the older procedures used in connection with low-tension mains, and these are dealt with fully.

Fault localising and testing cover a wide field and involve the use of a variety of apparatus, so that mains engineers of limited experience may find difficulty in acquiring a general and balanced view of the subject as a whole. Their case is provided for in this volume by an admirable introductory chapter in which the subject is surveyed on general lines, references being given where necessary to later chapters in which particular aspects are dealt with in detail. It is pointed out that although developments in distribution and protection methods, and improvements in cables and accessories, have resulted in a great reduction in the number of faults per mile of cable per annum as compared with earlier years, yet with the enormous increase in the mileage of cable in operation, the subject of this book maintains its importance. The first step in dealing with a fault is to locate it, and the procedure to be followed for this purpose is described in a practical way. The matter is frequently urgent, but a hurried procedure may lead to the neglect of proper safety precautions. For instance, when a defective high-tension feeder is being repaired, danger may arise from feed-back from a low-tension network through what is normally a step-down transformer. Cases of this kind are dealt with.

The main chapters of the book describe methods of measuring insulation, capacitance and resistance, and contain appropriate diagrams and illustrated descriptions of the instruments employed; the testing of live networks; breaking-down faults; loop tests; the application of induction methods; and the other main aspects of the subject. It is not concerned with cable manufacture, but routine factory tests are dealt with and the method of spark testing, as a substitute for immersion in water, is described. This test is now advocated for unsheathed cable in the British Standard Specification. Throughout the book, reference is made to the specification concerned, a similar procedure being followed in connection with various official regulations.

CONNECTION OF STONEBRIDGE PARK POWER STATION TO THE GRID.—Stonebridge Park generating station, which for the past 30 years has provided an independent supply of electricity for the operation of trains between Euston and Broad-street and Watford, with branches to Richmond and Croxley Green, as well as for the lighting of Euston and St. Pancras stations, and most of the London Midland and Scottish goods yards in the area, is to be connected to the grid. For this purpose a cable is being laid between Stonebridge Park and the Willesden station of the London Power Company; and it will thus be possible for the former to supply power to the grid during "off-peak" hours. The plant in the Stonebridge Park station originally generated at 25 cycles per second, but the work of conversion to 50 cycles per second, which was decided upon just prior to the war, is nearly completed.

BRITTLE FRACTURE IN MILD-STEEL PLATES—II.

(*Continued from page* 18.)

THE contribution of Mr. D. E. J. Offord to the Conference on Brittle Fracture in Mild-Steel Plates, the report of which is continued below, dealt with "Fundamental Physical and Metallurgical Aspects of Brittle Steel."

FUNDAMENTAL ASPECTS OF BRITTLE STEEL.

Brittle failure in mild steel and other structural materials has caused much concern to the Director of Naval Construction, Admiralty, who considers that no effort should be spared to obtain a complete understanding of the phenomenon and its causes.

For some years, I was concerned with the proof testing of armour plate. These plates are made from alloy steel, usually nickel-chrome-molybdenum, with a most rigid control of composition, heat treatment and all processes of manufacture. The ordinary mechanical properties are defined within narrow limits. We did not always get consistent results. Occasionally, we would find a plate giving a resistance below that to be expected, and, on examination of the damage, bands of crystalline fracture were often apparent. The mode of manufacture aimed at obtaining good ductility and fibrous fractures. I was never able to obtain a satisfactory explanation for the occurrence of this phenomenon. The stresses in armour plate when attacked by shell are complex. There is a tendency for the plate to bulge, thus putting the material in biaxial tension in the plane of the plate. In the third direction, that is, through the thickness of the plate, it is generally thought that, on first impact, a compression wave travels through the plate, which is eventually reflected from the back surface as a tension wave. The interaction of these two waves is complex. It is possible, therefore, that, in certain circumstances, a state is reached in which the three principal stresses combine to give a shear-strain energy well below the value necessary for plastic deformation and yet large enough to overcome the natural cohesion of the metal. If this is the correct explanation, it shows some similarity between this type of failure and that in mild-steel ship plates which we are now considering. I might add that although the manufacturers have been very much alive to this type of failure in armour plates for many years, they have been unable so far to devise any composition or mode of manufacture which entirely eliminates it.

In 1932, bombing trials were carried out against an old battleship. One bomb struck and perforated the strength deck. An examination of the damage revealed a brittle fracture. The material showed little, if any, evidence of plastic flow and the fracture exhibited a crystalline appearance. Early in the war just ended, a fairly heavy underwater explosion occurred about 70 ft. below the keel of a large cruiser. The ship whipped violently and broke her back at a position near the forward nodal point. At this position there was some lack of continuity. The plates in the strength deck ruptured with little or no plastic deformation, and exhibited crystalline fractures. In both cases, portions of the adjacent plate were cut out and subjected to detailed metallurgical and mechanical examination. The results indicated nothing unusual. There is no evidence of fatigue due to the age of the ships, and in all cases the metal was fully up to the original specification requirements. In both these instances, the ships were riveted. I quote them to show that the incidence of brittle failure is not confined to welded construction. It must be noted that in both examples there was a relatively high rate of strain.

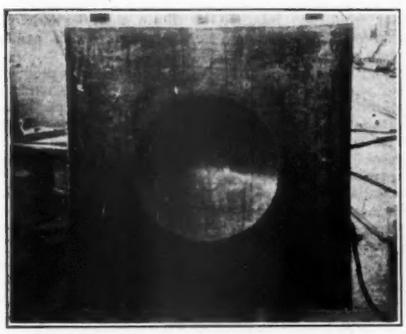


FIG. 24.

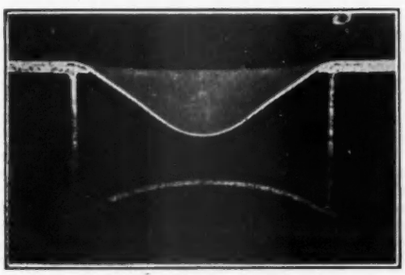


FIG. 25.

FIG. 26

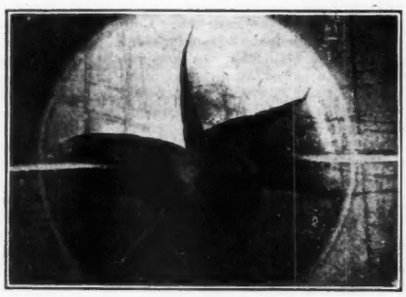


FIG. 27.

Some time ago, and as soon as the new structural research establishment was in a position to do so, the Director of Naval Construction instructed us to collaborate with Mr. W. G. John, Superintendent of Welding, and to carry out researches in connection with the brittle failure of welded mild steel under explosive loading. The target is a circular area about 2½ ft. in diameter in the middle of a ½-in. mild-steel plate about 5 ft. square. With a plain plate, the target area, when attacked, dishes into a shape which is approximately a paraboloid of revolution. The maximum dish which can be obtained without rupture is about 10 in. The behaviour is what would be expected from a ductile material. There is a mean elongation of about 16 per cent. and a maximum reduction of plate thickness of about 50 per cent. The plate is, of course, subject to biaxial tension. Fig. 24, herewith, shows a general view of the target and the dished plate. Fig. 25 is a section showing the profile of the dish and, less clearly, the reduction in thickness of the plate.

With a butt-welded joint across the centre of the plate, we find that it is ruptured by a much smaller charge than is required for a plain plate; less than one half, in fact. The fracture seems to start at the weld, but runs off into the parent metal. There is little or no reduction of area and the fracture has all the appearance of brittle failure. In all cases when mechanical tensile tests have been carried out on the welded joints, fracture has occurred well clear of the weld. If, instead of a butt-welded joint across the centre, we fit an uncut plate, but deposit one or more runs of weld metal across its centre, the plate is still ruptured by a charge less than one-half that required to rupture the plain plate and a brittle fracture is obtained. If one or more runs of weld metal are deposited on the uncut plate and then ground flat, a slightly larger charge is required to rupture the plate, but brittle failure still occurs. No improvement is obtained in charge required to rupture or in the type of fracture obtained if the plates are normalised at 900 deg. C. before use and/or heat treated to 650 deg. C. after welding.

Figs. 26 and 27, herewith, show typical examples of brittle failure which occurred in some of the cases just quoted. Other researches which we have carried out indicate that the earlier failure of the plate with weld deposits, etc., is not due to the increased mass effect, and there is some evidence that it may be due, at least in part, to relatively sudden change in geometric section, that is, lack of continuity. In cases when the excess weld metal is ground off, there is no change in geometric section, but there is lack of continuity in the structure of the material; that is non-homogeneity between the parent metal of the plate and the weld metal which has penetrated into it. During all trials, the targets are allowed to reach sea temperatures, and no work is done in sea temperatures of less than 40 deg. F.

Considering the manner in which these targets are constructed, and that no improvement is obtained by subsequent heat treatment at 650 deg. C., I myself feel that the brittle failure in these targets cannot be attributed to locked-up stresses, although further tests are required before I would consider the point definitely established. We are continuing our researches on these and similar targets, but there are so many unknowns and so many possible variables that a large number of targets are required to explore the behaviour of a single thickness and quality of material joined by one type of welding.

There is one other point which may be relevant. In both the cases of ship damage to which I have already referred, the plate in which brittle failure occurred was about ¾ in. thick. There have been during the war many cases of smaller warships, such as destroyers and sloops, suffering damage from underwater explosions resulting in buckling of the structure at or near a nodal point. The plating of the strength decks of these ships is usually less than ½ in. thick, and I do not think there have been many examples of brittle failure. In the underwater explosion targets which I have described, the plate in which brittle failure has occurred has been ½ in. thick. Some similar targets ¼ in. thick showed that, although a brittle fracture occurs in the weld metal, the fracture in the parent metal is of the type usual with ductile material. In the only two cases so far carried out with target plates 1 in. thick, one plate has failed by brittle fracture, although the plate had no welding or welding deposit near the target area. The evidence is far from conclusive, but there is a suggestion that thick plates are more prone to brittle failure than thin ones.

The experimental results quoted do not contribute towards solving the mystery of brittle failure—that was not the intention in bringing them to notice; it was rather to illustrate the complexity of the problem and to give some quantitative idea of the loss of efficiency which may occur in welded joints when the structure is required to withstand dynamic or impact loading. All that we seem to know about brittle failure is that it is a reality and that for dynamic or impact conditions its incidence is not confined to welded structures. We do not know to what extent it is a fundamental property of the material, or how far it depends upon subsequent local heat treatments, geometrical conditions, continuity, etc. The British Iron and Steel Research Association have rendered a great service to all branches of structural engineering in drawing attention to the importance and reality of the problem and in stressing the need for organised research of the highest priority, and on a wide scale.

(*To be continued.*)

CONTINENTAL ELECTRICAL-INSTRUMENT PRACTICE.

AN account of a discussion on "What has the Electrical Instrument Industry to Learn from Developments in Continental Practice?," which was held at a meeting of the Measurements Section, on Friday, February 7, 1947, has been published in the December issue of the *Journal of the Institution of Electrical Engineers, Part II.*

The discussion was opened by Messrs. F. E. J. Ockenden and G. N. Harding, who stated that the trend of instrument development in countries other than our own was a matter of major interest. Recent conditions had so reduced the normal interchange of information that we were largely in the dark in regard to Continental practice. A good deal of light, however, was now being shed on the position by the visits made to Germany and other ex-enemy countries by parties of technical investigators under the auspices of the British Intelligence Objectives Sub-Committee. A survey of their reports was of value in showing not only the direction in which Continental practice had moved ahead of ours, but equally those in which progress had been inferior or negligible. The effect of material shortages appeared to be even more marked, than in our own industry. Thus, synthetic sapphires, which presumably could have been obtained from Switzerland, seem to have been used only in small quantities. There was some indication that glass had been tried, though without success, and the bulk of "substitute" bearings were made of beryllium-copper, for which considerable claims were made. An interesting feature of many designs was the use of ring and end-stone bearings in place of the more usual conical variety. It was considered that the former were suitable not only for instruments having a high working torque, but also for small low-torque instruments in which the movement was kept "alive" by being mounted in a vibrating situation, such as the control panel of an aeroplane. For the latter use, the resistance to shock of such bearings was also a consideration.

Pivots and control springs appeared to be of standard design and material, high-carbon steel being used for the former and phosphor-bronze for the latter. Neither silicon-bronze nor beryllium-copper seemed to have found favour as spring materials, though, in view of its excellent elastic properties, the reason for the exclusion of the latter was not clear. Owing possibly to the shortage of both wood and of cast-iron, Bakelite cases were in very general use for all instruments of up to 6 in. in diameter, as well as for precision test sets and multi-purpose testers. Some small instruments were mounted in die-cast cases. Great care was taken in fitting the cover to the base and the spigot of the latter was usually machined to ensure an accurate fit. Lacquer was frequently used to seal the instrument, but otherwise nothing approaching British "hermetically sealed" or "tropicalised" cases was found.

Magnets were both of the cast and "bonded" variety, nickel-iron-aluminium-cobalt alloys being employed but frequently without the cobalt owing to the shortage of that material. Bonded magnets were widely used for small assemblies because of the ease with which complicated designs could be formed, and the facilities offered for the recovery of waste material by the simple expedient of dissolving out the bonding cement. Mouldings and die-castings were widely used in building-up movement assemblies, though the use of Bakelite moulding for precision instruments was deprecated on the grounds of instability. Low-grade moving-coil instruments were fitted with printed scales, but these were not employed for the higher grades or for moving-iron instruments and ohmmeters. An interesting scale-drawing machine incorporating a number of radial arms connected to a slotted flexible metallic ribbon was studied. It was stated that with this a 6 in. "moving-iron" scale having 150-divisions could be drawn in 15 minutes. Miniature indicators of the moving-coil pattern, having 270-deg. scales, were made and used in large quantities. The working portion of the coil was generally the axial edge; the working torque tended to be low and the damping poor. For short-scale instruments a well-known English design incorporating a central magnetic core was copied. By so magnetising the core that the field distribution was diametrical instead of radial, this instrument was modified to make it suitable for use as an ohmmeter employing two coils, one working in the strong (central) field and the other in the weak (fringing) field.

A notable advance in the measurement of direct-current was the development of a simple moving-magnet instrument of cheap design and robust construction with a scale length of about 100 deg. No springs or ligaments were necessary and the sensitivity was readily controlled by altering the spacing between the moving and the control magnets. Although at present designed for the mass production of light air-borne indicators having an accuracy of about 2 per cent., it was believed that there would be no difficulty in making it suitable for instruments of sub-standard accuracy. A ratio-meter movement had also been developed on similar lines. A feature of the instruments on German aircraft was the use as remote indicators of small instruments incorporating two arms of a self-balancing direct-current bridge. Many of these had movements no larger than would normally be built into a 3½-in. case. The core was of permanent-magnet material and the moving coil, in addition to carrying a short pointer, operated a set of brushes which travelled over a small self-contained resistor and constituted the self-balancing element. Both the resistor and the brush mechanism were extremely well made and reliable contact between them was maintained in spite of the necessarily low contact pressure. The general impression obtained from the evidence available was that the Germans had spared no effort to tool up their products to such a state that reliable components were assured. On the other hand, this policy carried with it restrictions on changes of design which must have influenced any subsequent modification and development.

During the course of the discussion, it was pointed out that the moving-magnet instrument might find applications in situations which would adversely effect spring-controlled instruments, such as a ratiometer for the investigation of temperature effects on rotor bars and other measurements made in the proximity of large machines. On the other hand, it was thought that the relatively heavy weight and power consumption of the movement and the possibility of inaccuracy on pulsating currents called for examination. In discussing the details of war-time Continental instruments, it was pointed out that the use of substitutes for sapphires was due not to shortage, but to the scarcity of suitable polishing materials, such as diamond dust. Metal-to-metal bearings were intended to cover the transitional period until glass and other suitable substitutes could be found. In this country, phosphor-bronze had been found to be reasonably satisfactory provided the bearing was formed by "dinting" under high pressure and not by machining. The use of beryllium-copper bearings was forced upon the Germans by the heaviness of their meter movements. Their failure to make a success of glass bearings was due to the lack of a suitable lubricant. This was not the result of any shortage but of inadequate investigation. It was reported that a leading German chemical firm had succeeded in "case-hardening" agate bearings by a heat treatment process, which gave a surface hardness nearly equal to that of a sapphire. Internal pivots were to be found in many German instruments, but their principal advantage—the possibility of producing a shallower instrument—had not been realised. In general, the instruments were deeper than ours using conventional external bearings. This was due to the popularity of conical rather than flat spiral control springs.

Dealing with the marking of meter scales, some speakers advocated the Continental custom of radial divisions only, while others preferred to retain the circumferential lines. The use of percentage scales, 0 to 150 per cent., with prominent 100 per cent. full-load markings, had been standardised in some stations abroad and was capable of easy adaptation on an expanding system. Many speakers expressed a preference for absolute indication of volts and amperes, but agreed that there was much to be said for the use of single-letter symbols to show the quantities indicated.

Attention was drawn to the widespread use and excellent appearance of recording instruments on the Continent. Less thought, however, had been given to the development of recording papers free from variations due to changes in humidity. Instrument transformers, particularly in Italy, where $16\frac{2}{3}$ cycle supplies were prevalent, showed a high standard of design with ratio errors of 0·1 per cent. and phase errors of about 0·1 centiradians. Several speakers praised the Continental factory organisation, as exhibited in such matters as the use of dustproof rubber-tyred trolleys for transporting parts for assembly, roll-top desk benches and built-in test equipment, but deprecated the tendency of manufacturers to dictate to the market in the matter of standardisation. It was generally agreed that the element of novelty in many Continental designs arose from the necessity for circumventing the lack of essential raw materials and that designers had little to show in knowledge, ability or ingenuity which we could not match or excel in this country.

RICHARDSONS, WESTGARTH AND COMPANY, LIMITED.—We have received from Messrs. Richardsons, Westgarth and Company, Limited, Northumberland Engine Works, Wallsend-on-Tyne, a brochure describing the work of that firm and their associated companies during the recent war. In all, the group provided propelling machinery for some 30 per cent. of the merchant tonnage built in the United Kingdom and Northern Ireland between 1939 and 1945, in addition to a large volume of repair work, transportable power stations, and a wide variety of auxiliary machinery, etc.

DIESEL ENGINES UNDERGROUND.*

By L. B. BERGER, M. A. ELLIOTT, JOHN C. HOLTZ and H. H. SCHRENK.

DIESEL-POWERED locomotives designed specifically for underground operation were used in the construction of some of the tunnels that comprise the Delaware Aqueduct in New York State. Before this there had been limited use of Diesel-powered equipment in tunnel construction in various parts of the country, but this equipment was used without modification for underground work and, in some instances, apparently without due consideration of the hazards that might be created by the introduction of fuel-burning equipment into confined underground spaces. As certain definite advantages were apparent if Diesel haulage could be used in tunnel construction in some sections of the Aqueduct, the contractors who were to construct the tunnels in these sections were desirous of using this type of haulage equipment if it could be employed with safety. This matter was given consideration by the various agencies concerned with the establishment of safe practices on the aqueduct project before tunnel driving was started. Of chief concern were the quantities of toxic or objectionable materials that would be discharged into the tunnel air by the exhaust of the locomotives, and the volume of ventilating air that would be required to dilute these exhaust-gas products to concentrations permissible in the atmosphere of working places.

The Bureau of Mines was interested in this proposed use of Diesel locomotives for underground haulage, not only with regard to the safety of this particular installation but also because of an increasing general interest on the part of the mining industry in the possibility of Diesel haulage in coal and metal mines. Anticipating a need for information to evaluate the hazards that might be created by the use of Diesel engines underground, the Bureau initiated, in 1937, a programme of research, the first phase of which was a study of the composition of exhaust gas produced by Diesel engines under various operating conditions. The experience gained was applicable to the questions of tunnel-air contamination and ventilation involved in the proposed use of Diesel locomotives in construction of the aqueduct tunnels. After discussions among interested agencies, the Division of Industrial Hygiene of the New York State Labour Department granted permission to install one locomotive, which was to be tested by the Bureau of Mines before it was put into service to determine the quantity of ventilation that would be necessary to insure that unsafe or unhygienic conditions would not be created in tunnel atmosphere. The first locomotive was put into service in August, 1939, and, on the basis of experience with this equipment, 10 locomotives were installed eventually, five being used on each of two tunnel contracts.

The two contracts on the aqueduct on which Diesel locomotives were used totalled approximately 25 miles of tunnel. The tunnels on one contract were developed from three shafts spaced approximately five miles apart and on the other contract from two shafts similarly spaced. Tunnel diameter in the rough was 17 ft. to 18 ft., and when lined with concrete was to be 13 ft. 6 in. The maximum haulage distance was five miles on one contract during lining of the tunnel with concrete. With the long hauls involved and the large tonnage of material to be handled during tunnel driving and lining, it is evident that selection of the most efficient and economical haulage system was important.

Three choices of haulage methods were open to the contractors: storage-battery locomotives, trolley locomotives, and Diesel locomotives. Comparative estimates of the cost of the three types of haulage systems definitely favoured Diesel haulage for use in lining a tunnel from the standpoint of initial installation cost.

All the Diesel locomotives used on the Delaware Aqueduct were built by one manufacturer. The locomotives are equipped with four-stroke cycle, six-cylinder Diesel engines of 5-in. bore and 6-in. stroke, having a piston displacement of 707 cub. in.; the maximum governed engine speed is 1,700 r.p.m. The engine is cooled by water circulated through the cylinder jacket to two radiators mounted one on each side of, and just forward of, the operator's compartment. Air is drawn through the radiators by multiple axial-flow fans located in a compartment at the centre of the locomotive. The air discharged by these fans is used to dilute the engine exhaust gas before it is finally discharged from the locomotive. The exhaust manifold of the engine is water-jacketed, the jacket being included in the engine-cooling system.

The fuel is carried in a tank located behind the front cross member of the locomotive frame and is transferred from this tank by an auxiliary pump, through a filter, to the fuel-injection pump, which is of the individual plunger type with fuel delivery controlled by a pump-

---

* Reprinted from Report of Investigations, No. 4032, United States Bureau of Mines. (Abridged.)

plunger by-pass. Fuel-injection valves are of the circumferential orifice (pintle-nozzle), conical valve-seat type. Fuel injection is controlled by a hand throttle in the operator's compartment and a governor built into the engine.

The exhaust gas is discharged from the engine through the water-jacketed manifold and travels thence through a vertical pipe to an exhaust-cooling box partly filled with water and located behind the front cross member of the locomotive frame. A water spray nozzle is tapped into the top end of this pipe and is supplied with water from a tank by a separate water pump. Water from the spray travels downwards through the pipe in contact with the exhaust gas to the first exhaust-cooling box. The exhaust gas is discharged under water in this box and travels thence to the top of the box, where baffles are interposed to stop water spray. After leaving the first cooling box, the exhaust gas passes to a second cooling box on the opposite side of the locomotive.

After leaving the second cooling box, the exhaust gas passes to a chamber containing a device intended to prevent propagation of flame from the interior of the exhaust system to the atmosphere surrounding the locomotive. In the first locomotive, the flame-arresting device consisted of a stack of closely-spaced metal plates; in the locomotives built at later dates the metal plates were supplanted by a bed of shaped ceramic pieces, or "saddles."

After flowing through the flame-arresting device, the exhaust gas passes to the fan chamber mentioned in connection with the engine-cooling system. The exhaust is mixed with the air delivered by the radiator cooling fans and is discharged from the locomotive through a rectangular opening at the centre of the side of the locomotive. The purpose of diluting the exhaust with air is to prevent local high concentrations of exhaust gas in the immediate vicinity of the locomotive. The flow of exhaust gas from the engine to the final exhaust is shown in the accompanying diagram. The intake air to the engine passes through two automotive-type air cleaners in parallel, through a flame-arresting device consisting of a stack of spaced metal plates, and thence to the intake manifold.

Tests of the first Diesel locomotive built for use on the aqueduct were made by the Bureau of Mines at the plant of the manufacturer. The object of these tests was to determine the concentrations and quantities of toxic gases produced by the engine under various operating conditions in order that a preliminary estimate might be made of the quantity of ventilation required in the tunnels of the aqueduct to dilute these gases to concentrations permissible in the air of working places.

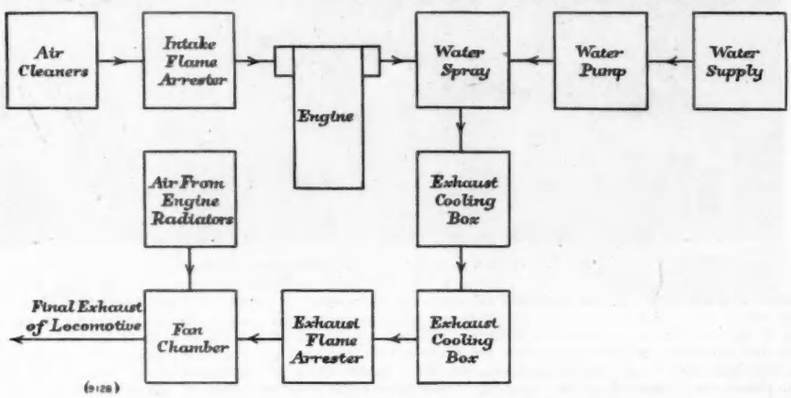


TABLE I.—PERFORMANCE OF ENGINE AND EXHAUST-COOLING SYSTEM.

	Low Engine Speeds.				High Engine Speeds.		
Test number	1.	2.	3.	6.	5.	4.	7.
Engine speed, r.p.m.	530 Idling	700 Intermediate	800 Intermediate	900 High	1,730 Minimum	1,700 Intermediate	1,600 High
Engine power output							
Fuel-air ratio, lb. per lb.	0·010	0·026	0·025	0·048	0·014	0·038	0·050
Fuel consumption, lb. per hr.	4·0	14·9	11·7	33·2	18·0	33·0	53·3
Volume of exhaust gas*:							
Cub. ft. per lb. of fuel	1,330	495	513	257	917	327	244
Cub. ft. per hr.	5,300	7,400	6,000	8,500	16,500	10,800	13,000
Piston displacement, cub. ft. per hr.	6,500	8,600	9,800	11,000	21,100	20,800	19,600
Water pumped through exhaust-cooling spray, gal. per hr.	1·7	1·9	2·0	1·6	2·8	2·9	4·3
Water lost from exhaust cooling boxes, gal. per hr.	0·0	0·6	1·0	5·2	6·9	11·2	24·0
Exhaust gas temperature, deg. F.:							
At outlet of water-cooled exhaust manifold	170	385	360	670	365	370	815
At outlet of first exhaust-cooling box	97	120	124	147	122	147	185
At outlet of second exhaust-cooling box	97	120	122	147	122	144	185
Temperature of final exhaust (mixture of exhaust gas and radiator cooling air), deg. F.	108	128	130	147	—	133	156
Surface temperature of exhaust pipe at outlet of water-cooled exhaust manifold, deg. F.	—	—	—	450	—	400	—
Pressure at inlet of first cooling box (total back-pressure on engine), in. of water	8	10	1	14	25	20	—

* As dry gas at 60 deg. F. and 29·92 in. of mercury; calculated from composition of fuel and of exhaust gas.

TABLE II.—COMPOSITION OF EXHAUST GAS.

	Low Engine Speeds.				High Engine Speeds.		
Test number	1.	2.	3.	6.	5.	4.	7.
Engine speed, r.p.m.	530 Idling	700 Intermediate	800 Intermediate	900 High	1,700 Minimum	1,700 Intermediate	1,600 High
Engine power output							
Fuel-air ratio, lb. per lb.	0·010	0·026	0·025	0·048	0·014	0·038	0·050
Composition of engine exhaust gas, per cent. by volume:—							
Carbon dioxide	1·96	5·46	5·27	10·55	2·95	8·28	11·14
Oxygen	18·13	13·33	13·66	6·41	16·79	9·56	5·48
Carbon monoxide	0·08	0·03	0·02	0·03	0·04	0·03	0·02
Methane	0·02	0·00	0·02	0·00	0·01	0·00	0·00
Nitrogen	79·81	81·18	81·03	83·01	80·21	82·13	83·36
Oxides of nitrogen, parts per million:—*							
At outlet of exhaust manifold	101	388	356	996	315	476	715
After exhaust-cooling boxes	117	358	274	805	232	444	589
Composition of final (diluted) exhaust, per cent. by volume:—							
Carbon dioxide	0·21	0·63	—	0·82	—	0·72	0·96
Oxygen	20·71	20·04	—	19·75	—	19·91	19·70
Carbon monoxide	0·00	0·01	—	0·01	—	0·01	0·01
Methane	0·00	0·00	—	0·00	—	0·00	0·00
Nitrogen	79·08	79·32	—	79·42	—	79·36	79·33

* As nitrogen dioxide (NO_2); not included in sum of percentages of other gases.

For these tests, the complete locomotive was mounted on a dynamometer test stand, so that the engine might be operated at various speeds and power outputs, the power delivered to the driving wheels of the locomotive being absorbed by a Prony brake system. Provisions were made for sampling the exhaust gas as it left the engine; after passage through the water of the exhaust-cooling boxes, and after its dilution with air from the fans of the engine-cooling system. In addition to gas sampling, observations were made of engine speed, fuel consumption, exhaust-gas temperatures and pressures, exhaust-cooling spray water consumption, and water lost from the exhaust-cooling boxes. Tests were conducted at low and at high engine speeds, and in each speed range the engine was operated at minimum, intermediate, and high power output.

The test results are given in Tables I and II, on this page. From Table II it may be noted that of the exhaust-gas constituents determined in the tests, carbon monoxide, oxides of nitrogen, and carbon dioxide are of chief significance from the standpoint of toxicity. Other objectionable constituents that may be present in Diesel exhaust, although not determined in these tests, are aldehydes, smoke, and oxides of sulphur. The concentrations of carbon monoxide and oxides of nitrogen were in general conformity with the results obtained in comparable laboratory tests of smaller Diesel engines, and were not considered unduly high if adequate ventilation was provided in the tunnels where the locomotive was to be used.

It may be noted that the carbon-dioxide content of the exhaust increases with increasing power output, or fuel-air ratio, representing the relationship between quantity of fuel burned and power produced. It may be noted, also, that even at the maximum power output observed (test 7) the exhaust contained considerable oxygen or excess air. The fuel-air ratio in this test was 0·05 lb. of fuel per pound of air. If the power output of the engine had been increased by injection of a greater quantity of fuel on each power stroke until a fuel-air ratio of 0·069 had been reached, theoretically just enough air would have been present during combustion in the engine cylinders to burn all the carbon of the fuel to carbon dioxide and all the hydrogen of the fuel to water vapour. Actually, however, when this "chemically correct" mixture is approached it becomes increasingly difficult for combustion to proceed to completeness in the Diesel engine, and increasing quantities of carbon monoxide are formed and are discharged in the exhaust gas. If the chemically correct fuel-air ratio is exceeded and there is definitely not enough air for complete combustion, the exhaust of the Diesel engine contains a large proportion of carbon monoxide and would be a decided hazard underground.

It is evident, therefore, that delivery of the fuel pump of a Diesel engine that is to be used underground must be limited so that the engine cannot be operated at fuel-air ratios that would produce dangerous concentrations of carbon monoxide in the exhaust gas. As the maximum fuel-air ratio attainable in the tests of the locomotive was 0·05, at which condition the exhaust contained only 0·02 per cent. of carbon monoxide (test 7), it was recommended that the adjustable stop that limits maximum fuel injection by the fuel pump be locked in position and sealed so that the engine could not be operated at higher and unsafe fuel-air ratios when put into actual service.

(To be continued.)

THE GAUGE AND TOOL MAKERS' ASSOCIATION.—The Gauge and Tool Exhibition, which has been organised by the Gauge and Tool Makers' Association, will be held from Monday, January 26, to Friday, February 6, inclusive, at the New Hall, Vincent-square, Westminster, London, S.W.1. A trade luncheon of members and guests of the Association has also been arranged and will take place at the Savoy Hotel, Strand, London, W.C.2, at 12.30 for 1 p.m., on Thursday, February 5. Further particulars are available on application to the secretary, the Gauge and Tool Makers' Association, Standbrook House, Old Bond-street, London, W.1.

CONFERENCE ON SAFETY IN CIVIL AVIATION.—A full-day discussion on "Safety in Civil Aviation" will be held under the auspices of the Royal Aeronautical Society, at the Institution of Civil Engineers, Great George-street, London, S.W.1, on Saturday, April 3. The morning session begins at 11 a.m., when Air Vice-Marshal D. C. T. Bennett, C.B., D.S.O., F.R.Ae.S., will speak on "The Economics of Safety." He will be followed, at noon, by Professor A. A. Hall, M.Sc., M.A., F.R.Ae.S., who will deal with "The Problems of Air-Traffic Control." There will be an interval for lunch from 1 to 2.30 p.m., after which Dr. K. G. Bergin, M.A., M.B., B.Chir., A.F.R.Ae.S., will speak on "Physiological Aspects of Safety." General discussion will take place from 3.30 p.m. to 6.30 p.m., except for an interval for tea from 4.30 to 5 p.m. Further particulars regarding the meeting may be obtained from the secretary of the Royal Aeronautical Society, 4, Hamilton-place, Piccadilly, London, W.1.

THE NELSON RESEARCH LABORATORIES OF THE ENGLISH ELECTRIC COMPANY.

THE Research Laboratories of the English Electric Company, Limited, at Stafford, which are named after Sir George Nelson, chairman of the company, may be divided into two main groups: the first adjoins the works and comprises buildings occupying a site of about four acres and providing a laboratory floor area of 70,000 sq. ft. In these laboratories, high-power and high-voltage investigations are carried out, as well as research into chemical, insulation, physical, electrical, radiological, electronic and metallurgical problems. The high-voltage laboratory and the first stage of the high-power laboratory were completed in 1938, while the other laboratories, except that used for metallurgy, were put into service a year later. At the same time, it was decided to proceed with a second high-power laboratory. Work was stopped, however, soon after the outbreak of war and was not resumed until 1944. Meanwhile, the metallurgical laboratory had been completed. The second group of laboratories, which is situated at Blackheath-lane, Stafford, is housed in buildings which were used for testing aeroplane engines during the war. These have been specially re-arranged for the construction and investigation of the special plant used in nuclear-physics research. At present, this work is divided into four sections, which are concerned, respectively, with high-voltage electrostatic generators, synchrotrons, high-voltage impulse equipment for accelerating electrons and X-rays, and the study of radiations. In what follows we give a description of the high-power laboratory, but it must be emphasised that this forms only one of the steps that have been taken by the English Electric Company to carry out planned research on the broadest lines.

The high-power laboratory comprises two installations, which can be operated either independently or in parallel to produce instantaneous short-circuits of 2,500 MVA at all standard voltages from 11 kV to 264 kV. With this equipment a practical study can be made of the behaviour of switchgear, generating plant, transformers and reactors under fault conditions. Power for these tests is obtained from two sets, each of which consists of an induction motor and alternator with associated separate exciters of special design. The motor of the main sets, one of which can be seen in the foreground of Fig. 1, is of the slip-ring induction type and has a continuous rating of 1,500 h.p. It is supplied with three-phase alternating current at 6·6 kV and runs at a speed of 3,000 r.p.m. This motor is used for bringing the set up to speed before the tests are begun, and is controlled by a liquid resistance in the rotor circuit. When the alternator, which can be seen in the background of the same illustration, is short-circuited to make a test, a resistance is connected in series with the rotor, the amount of which is adjusted to ensure that the disturbance to the network is a minimum. The motor is provided with dynamic braking equipment, which is applied automatically in case of an electrical failure on the alternator. It can also be applied manually to bring the machine to rest after the completion of a test programme, thus reducing the time required for this purpose from 45 minutes to 3 minutes. A slip coupling is provided between the motor and the alternator to prevent the torsional oscillations of the former from being transmitted to the latter. This coupling is made up of a number of spring-loaded Ferrodo friction discs and is set to slip when the load exceeds 2,500 kW.

The frame size of the alternator corresponds to that of a 70-MVA two-pole machine. Two standard voltages are obtainable, namely, 11 kV when the windings are connected in star, and 6·6 kV when they are connected in delta. The initial short-circuit reactance at 11 kV with star connections is 0·057 ohm, so that if a short-circuit occurs at the machine terminals when the excitation is normal, the initial symmetrical current in each of the windings is 110,000 amperes R.M.S. and the symmetrical output 2,100 MVA. This output however, is limited in practice by the transformers, which must be inserted to obtain the voltages higher than 11 kV that are invariably required. These high short-circuit currents in the stator windings produce forces on the conductors which necessitate the use of elaborate clamping and fixing arrangements. For instance, the non-magnetic core end plates are machined to the same shape as the stator slots at the points where the windings emerge. Special wedges of bakelised material, which have been cut to fit the windings, are also inserted, so as to form complete rings round the face of the stator. Further, the end windings are clamped to the stator face by phosphor-bronze bolts, which are screwed into the core end plate between each of the coils. The resulting construction is illustrated in Fig. 2, opposite. Another interesting point in the design is that the leakage reactance is reduced by inserting copper discs on both sides of each layer of the end windings. The connections between the windings and the terminals are made on rings, which are clamped to the core end plate and the face of the stator frame outside the evolutes. These rings are separated by packings, which are made of moulded bakelised wood. Six connections, two from each phase, are connected to the outgoing terminals and, in order to reduce the length of the leads to a minimum and to facilitate clamping, these six terminals are fixed radially on a cast-aluminium base, which is bolted to the top of the machine.

NELSON RESEARCH LABORATORIES, STAFFORD.

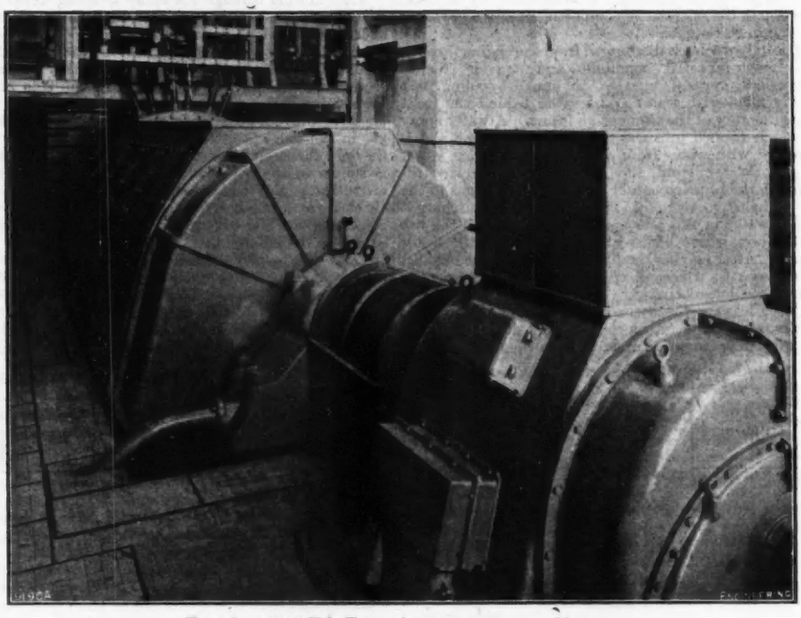


FIG. 1. 60-MVA TEST ALTERNATOR AND MOTOR.

While the alternator is undergoing short-circuit, rapidly oscillating torques are produced, owing to the losses in the machine windings and the interaction of the stator and rotor currents. These torques cause large forces to be transmitted from the stator frame to the foundation bolts and foundations. The feet of the welded stator frame have therefore been designed so that these forces are transmitted over a large area and 24 bolts, each 9 ft. long and 3½ in. in diameter, are employed to secure the frame to reinforcing girders at the bottom of the foundation. For the same reason, the foundation has been designed to withstand the maximum shock load of 300 to 400 tons which may be exerted during an asymmetrical single-phase short-circuit. This fouocation itself weighs about 350 tons, and is supported on 42 reinforced-concrete piles, which were cast *in situ* and driven to a depth of 35 ft. To avoid weakening of the foundation under the stator feet, the ventilating ducts have been placed at the end of the machine. The rotor, which was constructed from a forging of high-grade carbon steel, has an external diameter of 36 in. and weighs 30·5 tons. The stored energy at full speed is 110 million ft.-lb., but even so, the speed may drop by about 20 per cent. during a very severe short-circuit test. A maximum section of copper is, therefore, used in the excitation windings, and is supplemented by a small damper winding at the top of the slots. To ensure a continuous circuit for the current in the rotor keys the slot wedges are bonded along the body and at the end of the slots. The end bells are made of non-magnetic steel.

The main exciter set consists of a 750-h.p. 6·6-kV induction motor, which is coupled to a direct-current generator with a continuous rating of 1,800 kW. On the same shaft as these two machines is mounted a 12-ton flywheel, which provides the energy necessary to counteract the de-magnetising effect of the increased current in the alternator stator at the instant of short-circuit. This enables an output of 6,000 kW to be obtained for a short period. The machine is also designed to carry 16,000 amperes before the commutator flashes over. The magnetic circuit of the exciter has been specially designed to obtain the maximum rate of current rise in the rotor circuit, and in order to control its voltage accurately, its field is energised by a separate pilot exciter. The field of the latter machine is, in turn, energised from a separate supply and is controlled by a potentiometer resistance.

A "back-up" circuit breaker is connected between the alternator and the equipment under test so as to isolate the former at a pre-determined time. This circuit breaker, which has a symmetrical breaking capacity of 1,500 MVA at both 11 kV and 6 kV, is of the standard oil type, and consists of three single-pole units which are mounted on a common frame and are operated by solenoids. As it has to interrupt the short-circuit should the breaker under test fail, the stresses on the bushings and contacts are reduced by using four bushings per phase and connecting them in parallel in pairs. Heavy duty de-ion grids and the fixed main brush contacts are bolted to the lower extremities of the bushings, while the lift rods are made of bakelised wood to withstand the severe duty. This "back-up" circuit breaker is mounted in a cell directly opposite the alternator and is under observation from the control room.

Reactors, with a wide variation between the maximum and minimum values of resistance required, are provided to give the necessary range of short-circuit currents at different voltages. These reactors are of the air-core type with minimum electrostatic capacity to earth and between sections, in order to ensure that the natural frequency oscillation is as high as possible and that the circuit breaker is therefore subjected to the most severe conditions. There is one reactor per phase, those associated with the first of the alternators being divided into eight and those with the second into ten equal sections. The sections in each phase are spaced sufficiently far apart to reduce the mutual reactance and electrostatic capacity. Each section is rated to carry a short-circuit current of 20,000 amperes for five seconds, with an initial peak asymmetrical current of 50,000 amperes. The values of the individual reactances are chosen so that higher currents can be obtained by connecting two or more coils in parallel. With the first set of resistors it is possible, by the use of series-parallel switching, to obtain 72 values of reactance between 0·02 and 1·1 ohm per phase and thus, in combination with the different transformer connections, to produce the short-circuit currents required at any voltage. The reactors are connected to 'bus bars of flat copper strip, which are mounted vertically on the switchboards and are led to the 11-kV 'bus bars through isolators.

The power factor of the main circuit without the resistances in series is between 0·03 and 0·05. To increase these values so that the maximum output of the laboratory can be used for symmetrical breaking-capacity tests, resistances are connected in series with the reactors. These resistances consist of a bank of cast-iron grids comprising 16 equal sections in each phase, which are built into horizontal frames. These frames are arranged in tiers to allow the free passage of air for cooling. Each section is rated to carry 10,000 amperes for one second, higher values, up to 200,000 amperes, being obtained by connecting two or more sections in parallel. By arrangements similar to those provided on the reactors, the resistances in each phase can be varied between 0·008 and 2 ohms, with 70 intermediate values.

The majority of the tests made in the laboratory are

NELSON RESEARCH LABORATORIES, STAFFORD.

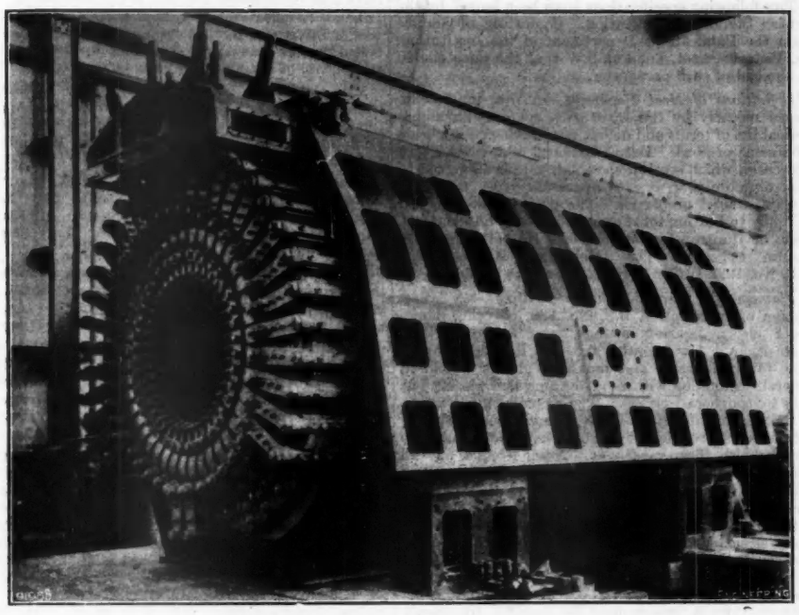


FIG. 2. STATOR OF 60-MVA ALTERNATOR.

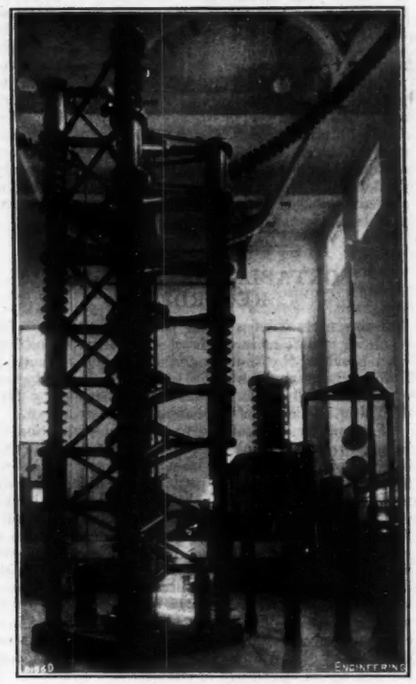


FIG. 3. 3,200-KV IMPULSE GENERATOR.

"break" tests, in which the circuit breaker under investigation is closed and the short-circuit is applied by a separate "make" breaker. This "make" breaker is installed between the reactors and the 11-kV 'bus bars. Its contacts, which are air-insulated, are clamped on bakelised-paper tubes and the conductors are arranged in the form of a U, so that the short-circuit forces assist the closing operation after the initial contact has been made. Each pole can be closed independently, thus enabling the short-circuit to be synchronised at a pre-determined point on the voltage wave of the alternator and enabling the test to be either symmetrical or asymmetrical. The three poles can also be coupled mechanically and electrically. Accelerating springs are provided so that the speed, when the contacts touch, is from 20 to 25 ft. per second, while the energy of the cross bar and mechanism is absorbed by dashpots after the contacts have been fully closed. The moving contacts are V-shaped steel castings, with removable copper blocks, which act as arcing contacts. There are four pairs of fixed contacts on each break.

Three outdoor single-phase transformers, with a three-phase rating of 70 MVA and a short-circuit reactance of 2·4 per cent., are installed to supply test voltages higher than 11 kV and to provide higher impedances than that obtainable from the reactors. These three transformers can be connected in delta or star for three-phase tests, or in parallel or series for single-phase tests. On the high-tension side, a voltage of 19 kV can be obtained with the windings in parallel, 38 kV with the windings in series-parallel and 76 kV with the windings in series. As the transformers are insulated for 114 kV to earth, it is possible to make three-phase tests with the neutral point insulated. By connecting the three transformers in series on the high-tension side, a maximum single-phase, voltage of 228 kV can be obtained with the mid-point of the middle transformer earthed. Special attention has been given to the layout of the high-tension bushings, so as to enable rapid changes to be made from one connection to another. A short length of transmission line connects the transformers to the outside test area and main high-tension cell. For voltages up to 33 kV, the high-tension side of the transformer can be connected to the main 'bus bars which feed the various test cells from the machine room. A separate transformer is provided to give the low impedance necessary for testing low-tension switchgear. This has one 6·35 kV winding per phase on the primary side, while on the secondary side there are four windings per phase, which are connected to terminals on the tank cover so that a pressure of 254 volts can be obtained. The connections and leads are interleaved to reduce the reactance. The high-tension windings can be connected in star or delta to give 11 or 6·35 kV, while the voltages available on the low-tension side are 0·254, 0·508, and 1·1 kV, with the phases connected in delta and 0·44, 0·88 and 1·76 kV when the connections are in star.

The control equipment for the various machines and switchgear, as well as the apparatus for initiating the tests and recording the various transient phenomena, is housed in a control room. The essential controls and instruments for the incoming feeders, the motors driving the alternator and exciter, the adjustment of excitation, the supplies for tripping and closing the main circuit breaker, and the test circuit breakers are mounted on a desk from which a clear view of the test cells and enclosure is obtainable. The controls for the timing device, the fire-protection system, and the roller shutters on the test cells are also operated from the desk, which is mounted on wheels, so that easy access to its equipment for inspection and maintenance is possible.

To enable the circuits of the various circuit-breakers and oscillographs to be operated in the correct sequence, a horizontal shaft on which 20 cams are mounted is used to open and close contacts fixed to a vertical panel on the top of the table. Each cam can be adjusted between 0 deg. and 360 deg., with reference to a zero line, without moving the others. For this purpose, the shaft is turned into a vertical position. The contacts are suitable for making and breaking currents up to 25 amperes, so that the main circuits can be connected to the cams without using intermediate relays. The cams are driven at a uniform speed by a motor through gearing and a clutch, which is operated from the control desk by a solenoid. After this clutch has been released, the cams make one complete revolution before the shaft is stopped and locked in its original position. Three speeds are available, so that the time of one revolution is 2, 4 or 8 seconds.

Owing to the transient nature of the phenomena, most of the measurements in the laboratory are recorded on oscillograms. A 12-element magnetic oscillograph, which is used for recording the low-frequency phenomena, and a three-phase cathode-ray oscillograph for recording such transients as those associated with the recovery voltage and the natural frequency phenomena, and a three-phase cathode-ray zero pause, are provided for this purpose. The connections between the oscillographs and measuring circuits are made with plugs and sockets, with special low-resistance contacts, the measuring circuits from the machine room being connected to the sockets and the oscillograph and timing-cam circuits to the plugs, so that there is no voltage on the latter when they are withdrawn.

Turning to the other laboratories in the group at the Stafford Works, the high-voltage laboratories are primarily engaged in determining the effects of atmospheric lightning disturbances in electricity supply networks under service conditions. The main equipment, therefore, consists of a 3,200-kV Marx type impulse generator, by which lightning effects are simulated, and power-frequency testing transformers for producing pressures up to 500 kV. A photograph of the impulse generator is reproduced in Fig. 3. The investigations in hand at present include the measurement of the breakdown voltages of porcelain and quartz under different conditions, and the application of voltage pulses at zero current to measure the recovery characteristics of mercury arcs. Work is also being done on the measurement of the impulse breakdown of insulating materials, with particular reference to short time breakdowns.

The chemical laboratory is divided into two sections, one dealing with analytical work and the other with the preparation and study of special resins and plastics. Plastics, oils and varnishes are also being studied in the insulation laboratory, which contains a Schering bridge for voltages up to 250 kV. Other work in this laboratory includes an investigation of the behaviour of alternator-coil insulation under high electrical and mechanical stresses; of the effect of capacitance and resistance grading on bushings and coils; and of the ageing of dielectrics by the variation in the impact strength of the material. Much of the work of the general physics laboratory is concerned with the standardisation of electrical measurements, the study of the magnetic properties of materials and the physical properties of conductors, semi-conductors and non-conductors.

The vacuum-physics laboratory is equipped for research and development work on all kinds of special vacuum apparatus, the problems under investigation at the moment being concerned with filament and electrode assemblies in accelerating tubes for high-voltage generators, and in "doughnuts" for synchrotrons. Work is also being done on the production of high-intensity X-ray pulses, on cold-cathode sources of electrons, and on a high-power modulator for linear acceleration systems. The work in the electrical laboratory includes the solution of the mechanical and electrical problems which arise in the design of the equipment manufactured by the company, and the development of apparatus for dealing with the difficulties encountered in the other laboratories. Among the investigations in progress are the study of the methods of separating the contacts of circuit breakers, the evaluation of the factors influencing de-ionisation in a gap, and electronic means of motor control. The electronics laboratory is equipped for light-current work generally, and is responsible for the introduction of electronic measuring and control equipment in all the other laboratories. Fundamental measurements in the high-frequency field are being undertaken and work is also being done on power-frequency networks using a transient calculating board which has been developed for the study of power systems under these conditions. An electronic generator has been devised for producing low-voltage impulses of different wave

forms to similate the high-voltage impulse generator. A second electronic generator is used to determine the transient recovery voltage characteristics of power networks. The metallurgical laboratory is equipped for melting and heat treatment under controlled atmospheres and vacua. It contains a two-high mill for hot rolling, a four-high mill for cold rolling, and high-frequency furnaces, so that special steels can be prepared and processed into rolled material. It is thus possible to study the properties of special alloys, such as the sheet steel used in transformers. Metallography, spectrographic analysis, and X-ray crystallography are also carried on, while in another section the extrusion of thin-walled ceramic tubes for low-loss high-frequency condensers, the slip casting of "doughnuts" for synchrotrons, and the glazing and metallising of electrical porcelains are undertaken.

PORTABLE WATER-LEVEL RECORDER.

A DESCRIPTION of a novel portable instrument for recording variations in the level of water in a tank has been provided by the London Midland and Scottish Railway Company (now the London Midland Region of British Railways). It has been designed by Mr. J. Walter, of the Chief Mechanical Engineer's staff.

It is sometimes necessary to record the variation of level of water in a tank or reservoir, but, except in the case of large units, the provision of a permanent instrument cannot always be justified. The instruments normally used consist of a rubber bulb immersed in the water, and connected to a pressure gauge by an air-tight pipe; the change of pressure corresponding to a variation of water level is recorded on a chart. There was, however, a demand for a portable instrument which does not depend on an air-tight connection, is compact and light in weight, and can be set to utilise the full width of the recording chart, whether it is employed in a comparatively deep or shallow tank. The instrument designed by Mr. Walter fulfils these requirements, and has the added advantage of simplicity.

It is based on the Principle of Archimedes; a body is suspended in the tank so that the variation in the proportion of it which is immersed, causes a variation in the effective weight of the body, and this is recorded on a chart. A sealed brass tube is suspended vertically from a spring, and the effective weight of the tube in water is equal to the actual weight, less an amount equal to the weight of water displaced. A pen connected to the spring by a suitable mechanism records the depth of water on a roll-type chart driven by clockwork. In order to render the instrument suitable for different tanks, the sealed tube is made of six 12-in. lengths of 1-in. diameter brass tube. Each length is sealed at both ends and provided with male and female screwed connections, so that six lengths coupled together are 6 ft. in length. When immersed in water, such a composite tube will respond to a 6-ft. variation of water level and the instrument is calibrated to ensure that the corresponding movement of the recording pen covers the full width of the chart. If, now, the tubes are divided into two lengths, suspended side by side, they will respond to a 3-ft. variation of water level, but will continue to use the full width of the chart without the need for recalibration. Similarly, if they are suspended as three 2-ft. lengths, or six 1-ft. lengths, they will be suitable for variations of 2 ft. or 1 ft., respectively. In all cases, of course, the tubes must be set so that the top ends are at high-water level.

To permit the arrangement of tubes to be altered, they are screwed into tapped holes in a crosshead, as required. The crosshead is attached to a brass chain, which, in turn, is fastened to a hook on the end of a piece of gut, passing over a pulley mounted on ball bearings, and attached at its other end to the spring. The recording mechanism and spring are in a box which can be placed at any convenient point on the side of the tank or reservoir. The pulley is carried on an arm which can be swung out to keep the tubes clear of the sides of the tank. When not in use, the tubes are packed in the box, which is 15 in. by 9 in. by 7 in. deep; the total weight is about 16 lb.

It is important always to use the full number of tubes, and to hang any surplus chain on the hook (after the apparatus has been erected to suit high-water level, etc.), otherwise the calibration of the instrument will be affected. There is an inherent source of error to which attention should be drawn. As the water rises and falls, the tubes will also rise and fall slightly due to the effect of the spring. The maximum movement of the spring, however, is about $\frac{3}{4}$ in., and therefore the error is only 0·5 per cent. for the 6-ft. range, and 3·1 per cent. for the 12-in. range. These inaccuracies were not considered serious, and, in any case, the water in a tank or reservoir is rarely still, so absolute accuracy is not practicable. The diameter, length, and number of tubes were determined by the use to which the first instrument was put, but it is possible to design an instrument to suit individual requirements.

BRITISH STANDARD SPECIFICATIONS.

THE following specifications have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Definitions of Heat Treatment.—A new publication issued recently by the Institution contains an alphabetical list of terms and definitions relating to the heat-treatment of steel. Heat treatment is described as a process in which steel in the solid state is subjected to one, or more than one, temperature cycle, to confer certain desired properties. The term is not intended to apply to heating for the sole purpose of hot working. Data on the transformation ranges in steels are given in an appendix. The publication is designated B.S. No. 1392-1947. [Price 2*s.*, postage included.]

Flameproof Electric-Lighting Fittings.—A new edition of specification B.S. No. 889, covering flameproof electric-lighting fittings, was issued by the Institution a few months ago. It included impact tests for well-glasses and bulkhead glasses which, in general, cannot be withstood by annealed glasses but only by toughened glasses. The recommended designs of well glasses, described in an appendix to the specification, can be toughened and can therefore be made to comply with the impact test. Other designs of well glass and bulkhead glass, however, particularly those with a prismatic or diffusing pattern, do not lend themselves to toughening. Lighting fittings provided with such glasses, however, are suitable for use in many situations where a flameproof fitting is required and where the risk of mechanical damage is not great. A revision of the specification has now been issued, making provision for two types of flameproof glass, namely, type A, which may be required to comply with all the tests on account of the exceptional risk of mechanical damage, and type B, which is not required to comply with the impact tests and, therefore, is suitable for less strenuous service conditions. The revision is issued in the form of an amendment slip, reference No. P.D. 721, copies of which may be obtained gratis on application to the Institution, enclosing a stamped addressed envelope.

BOOKS RECEIVED.

Ministry of Fuel and Power, and British Intelligence Objectives Sub-Committee. Technical Report on the Ruhr Coalfield. By a Mission from the Mechanisation Advisory Committee of the Ministry of Fuel and Power. Volume III. Appendix No. 13A. *A Rotary Rock Tunnelling Machine.* By DR. ING. W. VOGEL. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 9*d.* net.]

Breathing in Irrespirable Atmospheres and, in Some Cases, also Under Water. By SIR ROBERT H. DAVIS. The Saint Catherine Press Limited, 29, Great Queen-street, Kingsway, London, W.C.2. [Price 25*s.* net.]

Industrial Electric Motors. Some Hints on the Installation and Maintenance of Electric Motors and Generators. Second edition. Higgs Motors Limited, Witton, Birmingham. [Price 1*s.*]

How to Take, Keep and Use Notes. By DR. J. EDWIN HOLMSTROM. Aslib Pamphlets No. 1. Association of Special Libraries and Information Bureaux, 52, Bloomsbury-street, London, W.C.1. [Price 2*s.*]

The British Chamber of Commerce, France, Incorporated. Year Book, 1947. Offices of the Chamber, 6, rue Halévy, Paris (IXe).

Collection: Matériaux de Synthèse. Appareillage et Usinage des Matières Plastiques. Volume I. By J. LESCUYER. Dunod, 92, rue Bonaparte, Paris (VIe). [Price 1,380 francs.]

Newcastle, Industrial Capital of Australia, Offers Services, Facilities, Raw Materials and Opportunities to Manufacturers. The Electrical Engineer and Manager, Electric Supply Department, Greater Newcastle Council, Nesca House, King-street, Newcastle, N.S.W.

United States National Bureau of Standards. Building Materials and Structures. Supplement No. 2 to Report BMS17. *Sound Insulation of Wall and Floor Constructions.* Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 10 cents.]

The Province of Ontario in the Canadian Market. The Department of Planning and Development, Trade and Industry Branch, Queen's Park, Toronto; and Trade and Industry Department, Ontario House, Charles II-street, London, S.W.1.

Electricity Supply Meters. By A. E. B. PERRIGO. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 32*s.* net.]

The Journal of the Iron and Steel Institute. Volume CLIII. 1946. No. 1. Editor: K. HEADLAM-MORLEY, Secretary. The Secretary, The Iron and Steel Institute, 4, Grosvenor-gardens, London, S.W.1.

PERSONAL.

DR. R. L. SMITH-ROSE, M.I.E.E., who has been Superintendent of the Radio Division of the National Physical Laboratory since 1939, has been promoted to the new post of Director of Radio Research in the Department of Scientific and Industrial Research, for which a new station will be established eventually.

MR. C. K. F. HAGUE, M.I.Mech.E., A.M.I.E.E., managing director of Messrs. Babcock and Wilcox, Limited, has been elected President of the British Engineers' Association, 32, Victoria-street, Westminster, London, S.W.1.

REAR-ADMIRAL M. S. SLATTERY, C.B., R.N., who, until his recent retirement, was Vice-Controller (Air) in the Admiralty and chief naval representative, Ministry of Supply, is joining the board of Messrs. Short Brothers and Harland, Limited, in February.

MR. C. F. RUSSELL has been appointed chairman of the Aero Piston Ring Company, Limited. MR. L. H. MAIDMAN and MR. L. P. GIBSON, of Specialloid Limited, have joined the board of the Aero Piston Ring Company.

MAJOR H. J. HUMPHRYS, D.S.O., O.B.E., M.C., who has been Divisional Inspector of Mines for the Yorkshire Divison since 1933 has retired. He has been succeeded by MR. C. W. SCOTT, who has been District Inspector, Grade I, of the North Midland Division for the past nine years.

The United Steel Companies, Limited, 17, Westbourne-road, Sheffield, 10, announce that the following appointments have been made in the Appleby-Frodingham Steel Company, Scunthorpe. LT.-CDR. G. W. WELLS becomes joint general manager with MR. W. B. BAXTER. MR. A. ROBINSON becomes technical consultant and a member of the Appleby-Frodingham board. ENGINEER REAR-ADMIRAL C. W. LAMBERT becomes general works manager, and MR. A. JACKSON, MR. G. D. ELLIOT and MR. W. GEARY, works managers. MR. K. PATERSON takes over Engineer Rear-Admiral Lambert's duties as chief mechanical engineer, and MR. J. L. GASKELL is appointed chief electrical engineer.

MR. CHARLES LAWRIE has been made an additional general sales manager of the Vacuum Oil Company, Limited, Caxton House, Westminster, London, S.W.1.

MR. R. E. ELLIS has been appointed to fill the position of general manager of British Polar Engines, Limited, 139, Helen-street, Govan, Glasgow, S.W.1.

MR. E. A. GUTHRIE, A.M.I.E.E., has been appointed manager of the American Division of Metropolitan-Vickers Electrical Export Company, Limited, 1, Kingsway, London, W.C.2.

MR. ERNEST SOUCHOTTE, M.I.Mar.E., superintendent engineer of Messrs. Alfred Holt and Company, has been appointed to the engineering staff of Messrs. Harland and Wolff, Limited, and will take up his duties at Belfast on January 19.

MR. H. W. BAKER, B.Sc. (Eng.), chief engineer; MR. C. L. CRIPPS, manager of the Willesden factory; MR. J. W. FOLLETT, general sales manager; MR. A. G. ROSE, general manager of the King's Norton works; and DR. A. C. WAINE, B.Sc., head of the research department and chief chemist, have been elected directors of the Triplex Safety Glass Company, Limited. MR. ARTHUR COCHRANE has been made assistant managing director of the company.

MR. R. M. GILLIES, the London manager of Messrs. G. and J. Weir, Limited, Cathcart, Glasgow, S.4, retired on December 31 after 29 years in that capacity. MR. ANDREW C. SMITH has been appointed his successor.

MR. E. ARON, managing director of C.V.A. Jigs, Moulds and Tools, Limited, Hove, has now been appointed managing director of Messrs. E. H. Jones (Machine Tools), Limited, Edgware-road, The Hyde, London, N.W.9. MR. E. J. M. JONES is deputy managing director.

MR. G. F. WIX, who has assisted his father, the late MR. F. R. WIX, a director of the Phosphor Bronze Company, Limited, Witton, Birmingham, for the past two years, has now taken over his activities on behalf of that company. Mr. F. R. Wix, we note with regret, died on December 9.

The Chancellor of the Exchequer has appointed MAJOR J. H. MANDLEBERG to be chairman of the North-Western Regional Board for Industry, in succession to MR. GEORGE GIBSON, who has been made the first chairman of the North-West Area Board of the British Electricity Authority.

MR. J. L. HENDERSON, who was appointed director and general secretary of the Advertising Association in November, 1945, has now been made Public Relations Officer to the British Transport Commission, 55, Broadway, London, S.W.1.

MR. MAURICE OLLEY was presented with the I. A. E. Crompton Medal, for the session 1946-47, for his paper "Road Manners of the Modern Car," at the general meeting of the Automobile Division of the Institution of Mechanical Engineers, held on January 6.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—There was a fairly general restart at the steelworks on January 5, although a number of concerns, in accordance with previous arrangements, did not resume until the following day. A few steel manufacturing firms, notably the large tubeworks, were not in full operation until a week later. During the holidays, satisfactory progress was made with machinery overhauls and the repair and rebuilding of furnaces, although, of course, these were not so comprehensive as the major maintenance work taken in hand annually during the summer holidays. Nevertheless, the condition of the plant is now such as to ensure a smooth run at maximum capacity for the next six months. This will be possible however, only if continuity in the supply of essential raw materials is achieved. There is a feeling of quiet optimism among many makers that adequate supplies of metal will be made available in one form or another, although operating margins wil probably be very close. The more hopeful outlook is founded partly on the improved coal outputs, which should be reflected in higher coke production in England in the first instance. The new blast-furnace at Clyde Iron Works, belonging to Colvilles Limited, was lighted for the first time on Monday, January 12, after a series of disappointments regarding coke supplies since the unit was completed some months ago. The potential output of the firm's pig-iron furnaces there has thus been raised to 600,000 tons per annum. It is hoped that 2,000,000 tons of ingot steel will be produced during 1948. Semi-official estimates have put the output in 1947 at about 1,900,000 tons, compared with 1,764,000 tons in 1946. Owing to the effect on costs, makers are endeavouring to avoid the use of too large a proportion of pig-iron in the melting-furnace charge, although it is appreciated that less than the customary percentage of scrap will have to be used at times. The national scrap collection campaign is being actively supported in Scotland with this in mind.

Scottish Coal.—In the final week of 1947, the tonnage lost through holidays and other causes was 313,000, against 4,120 in the preceding week. Deep-mine production for the year has now been officially given as 22,973,185 tons. Reduced to a 52 weeks basis, the output showed a negligible improvement on the 1946 figures, but production towards the end of the year, which was at an annual rate of 25,000,000 tons, gave cause for gratification. All the pits restarted on the appointed day after the New Year holiday. Attendance was about 97 per cent. of that on a normal Monday, but outputs were several thousand tons below the average due to underground "stiffness" and time lost in redding up falls. These difficulties, however, were rapidly overcome and there have been indications that production may soon be restored to last month's level. Exports have been mounting steadily since the start of 1948, and considerable cargoes have been stemmed for Eire, Portugal, Sweden, and France.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Steel production is being steadily maintained, and in some instances increased a little, but not sufficiently to meet all requirements of the rolling mills and forges, and the consumers of sheet and bar. More iron and steel scrap is needed for re-melting. The demand for local brands of pig-iron and hematite iron is very heavy. Inadequate supplies of hard coke are restricting operations. Sheffield has been chosen as the centre of British steel research and temporary premises have been acquired for a metal-flow laboratory pending the acquisition of a suitable site for a new building. The team, now working on an experimental mill at Sheffield University, will shortly occupy the temporary premises, but are able to take measuring equipment to steelworks and demonstrate the measurement of forces on rolls. The data acquired are expected to play an important part in the construction of new rolling mills which, under improved methods, will be operated at up to 99 per cent. of capacity and effect considerable savings in fuel. At the works of Messrs. Thos. Firth and John Brown steady progress is being made in the conversion of armour-plate shops to heavy-engineering projects. One section is now producing components for marine engines, and, in another, work is proceeding on the erection of a press for the manufacture of motor-car wheels.

South Yorkshire Coal Trade.—Supplies are more satisfactory, and industrial users are much better placed for coal but supplies of hard coke are not coming forward promptly. Locomotive hards are in strong demand and in fair supply. Efforts are being made to increase the allocation of coking coal, supplies of which have been short of requirements for some time. Rather fuller supplies of coke-oven gas are flowing through the South Yorkshire Gas Grid and other pipelines from coke works. The consumption of electricity for industrial purposes has been reduced by about 30 per cent. by staggered hours of working.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The aggregate tonnage output of iron and steel is being maintained at a very high level; the demand is unabated and there are prospects of continued extreme pressure for supplies of Teesside products throughout the year. Recent achievements suggest that the industry is capable of exceeding the present heavy output if adequate quantities of pig iron and scrap are obtainable and the promised substantial supplies of the latter from Germany would be very welcome. Hopes are entertained of an early improvement in the yield of Cleveland ironstone; the output is barely 60 per cent. of pre-war production so that extensive consumption of costly foreign ores is necessary. Makers of semi-finished steel are still unable to cover the users' requirements completely, but satisfactory parcels of ingots are reaching the heavy rolling mills.

Foundry and Basic Iron.—North-East Coast foundry pig-iron consumers have now to draw supplies almost entirely from producing areas at a distance, as the local output has fallen to a very low level. The bulk of the tonnage being used is from the Midlands and the total supply available is not sufficient to cover current needs. The production of basic iron is readily taken up for the requirements of the local consuming plants.

Hematite, Low-Phosphorus and Refined Iron.—Hematite manufacturers continue to deal satisfactorily with the requirements of their regular consumers but are unable to supply iron for stocking purposes. Makers of low- and medium-phosphorus grades of iron have difficulty in meeting the demand; and firms turning out refined iron have ready outlets for their products.

Manufactured Iron and Steel.—Producers of semi-finished and finished iron and steel have sufficient orders to ensure great activity of their plants for a considerable time and buyers are in the market with further substantial orders. Steel billets and sheet bars are still unobtainable in quantities sufficient to cover the requirements of the re-rollers. Only very moderate parcels are coming to hand from overseas, but home production is on a slightly improved scale. Finished-steel firms have very heavy commitments and the cancellation of unexecuted contracts appears to be unavoidable. The heavy demand for larger deliveries of colliery equipment, railway material, shipbuilding requisites, and black and galvanised sheets continues.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Welsh Coal Trade.—Plans for reorganising the South Wales and Monmouthshire coalfield have been outlined during the past week after joint discussions between the Divisional Coal Board and the miners' leaders. Reference was made to undertakings which may be stopped and three collieries were named. By closing these pits and transferring the miners to nearby collieries where the coal reserves could be worked more easily and economically it was considered that materially increased production would be achieved. The steam-coal market has been concerned during the past week mainly with the home trade, but although most of the potential outputs for some time to come had been earmarked for delivery to this section there were encouraging signs of a steady revival in the export trade. The trade agreement with the Argentine, under which Britain was to resume coal shipments immediately, was welcomed, since in pre-war days the greater part of the coal which Argentina took from this country came from South Wales. In addition, during the past week, a second cargo of 3,100 tons of bituminous coal has been allocated for delivery to France. It was reported that the intention was to send France about 6,000 tons of coal each week, to be supplied by whichever district had coal to spare. Further business was expected from Portugal later this month, but as yet there has been no definite allocation. Shipments to Eire have been hampered by the increased cost of bunkers, shipowners normally engaged in the trade preferring to find employment in the coasting and Northern Ireland sections where the price increase was only 2*s.* 6*d.* per ton rather than pay the 25*s.* per ton extra which applies to Eire and foreign countries. Cokes and patent fuel continued in brisk request and supplies were difficult to stem for some time ahead.

Swansea Steel-Sheet Industry.—The market report issued by the Incorporated Swansea Exchange states that, last week, the demand for tin-plates was a little stronger and more orders were placed by home consumers for delivery during the current quarter, and, in some instances, later. In the export market, business was more active and the sales were numerous. Steel sheets continue to be sought after, and, as makers are heavily committed for some months ahead, orders are not easily placed. There is an insistent demand for iron and steel scrap, and users would welcome much larger deliveries.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTE OF TRANSPORT.—Monday, January 19, 5.30 p.m., Institution of Electrical Engineers, Victoria-embankment, W.C.2. "Transport: Amenity Requirements in a Public Service," by Messrs. C. Barman and M. G. Bennett.

CHEMICAL SOCIETY.—Monday, January 19, 6 p.m., University College, Swansea. "Physical Chemistry of Vacuum Metallurgical Processes," by Dr. P. Gross.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Mersey Centre:* Monday, January 19, 6.30 p.m., Royal Institution, Colquitt-street, Liverpool. "Standardisation of Power Cables," by Mr. W. H. L. Lythgoe. *Radio Section:* Tuesday, January 20, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "To What Extent Does Distortion Really Matter in Speech Transmission?" opened by Mr. P. P. Eckersley. *Western Centre:* Wednesday, January 21, 5 p.m., Merchant Venturers' College, Bristol. "Oil Deterioration in Transformers and Switchgear," by Mr. H. Hurworth. *Transmission Section:* Wednesday, January 21, 5.30 p.m., Victoria-embankment, W.C.2. "Lightning Strength of Power Transformers," by Mr. E. T. Norris. *Installations Section:* Thursday, January 22, 5.30 p.m., Victoria-embankment, W.C.2. "Design of Contactors," by Mr. B. Feldbauer.

INSTITUTE OF WELDING.—*North London Branch:* Monday, January 19, 7.30 p.m., 26, Portland-place, W.1. "Welding of Bridges and Buildings," by Mr. S. M. Reisser. *West of Scotland Branch:* Wednesday, January 21, 6.45 p.m., 39, Elmbank-crescent, Glasgow. Film Display.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 20, 5.30 p.m., Great George-street, S.W.1. Symposium on "Winter Conditions and the Civil Engineer."—"Roads," by Mr. Stanley Mehew; "Railways," by Mr. W. K. Wallace; "Municipal," by Mr. H. J. B. Manzoni; "Drainage and Inland Navigation," by Mr. Ben Howorth; "Meteorology," by Professor David Brunt, F.R.S. *Yorkshire Association:* Wednesday, January 21, 7 p.m., University, Leeds. With INSTITUTION OF STRUCTURAL ENGINEERS (*Yorkshire Branch*). "Pre-Stressed Pre-Cast Reinforced Concrete," by Mr. Kurt Billig.

CHEMICAL ENGINEERING GROUP.—Tuesday, January 20, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Abrasion, Erosion and Corrosion," by Dr. C. H. Desch, F.R.S.

INSTITUTE OF REFRIGERATION.—Tuesday, January 20, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, S.W.1. General discussion on "Constructional Methods of Insulation."

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Tuesday, January 20, 6.15 p.m., 2, Savoy-hill, W.C.2. "Foreign Electrical Engineering Practice," by Mr. C. W. Marshall. Wednesday, January 21, 7 p.m., 90, Deansgate, Manchester, 3. "Electricity Act, 1947," by Mr. H. Nimmo.

INSTITUTION OF THE RUBBER INDUSTRY.—*London Section:* Tuesday, January 20, 7 p.m., Caxton Hall, Victoria-street, S.W.1. "Industrial Design and the Rubber Industry," by Mr. Robert Cantor.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*London Associate Members' Section:* Wednesday, January 21, 6.30 p.m., 1, Grosvenor-place, S.W.1. Annual Meeting. "Refrigeration," by Mr. E. A. Friday.

INSTITUTION OF PRODUCTION ENGINEERS.—*Wolverhampton Section:* Wednesday, January 21, 7 p.m., Wisemore Schools, Walsall. "Fine Surface Finishes," by Mr. H. W. Lawton. *Birmingham Section:* Wednesday, January 21, 7 p.m., James Watt Institute, Birmingham. "Induction Heating," by Mr. E. May. *Western Section:* Wednesday, January 21, 7.15 p.m., Grand Hotel, Bristol. "Inspection of Production," by Mr. F. Nourse.

INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, January 22, 6 p.m., 11, Upper Belgrave-street, S.W.1. "Design of Structures in Areas Subjected to Mining Subsidence," by Dr. K. W. Mautner. *Midland Branch:* Friday, January 23, 6 p.m., James Watt Institute, Birmingham. "Design of Welded Structures," by Mr. R. G. Braithwaite.

INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 23, 5.30 p.m., Storey's-gate, S.W.1. Thomas Lowe Gray Lecture, "The Gas Turbine and Marine Propulsion," by Mr. T. A. Crowe. *London Graduates' Section:* Saturday, January 24, 3 p.m., Storey's-gate, S.W.1. "The Engineer and Steelmaking," by Mr. A. Roebuck.

JUNIOR INSTITUTION OF ENGINEERS.—Friday, January 23, 6.30 p.m., 39, Victoria-street, S.W.1. "Trade Marks," by Mr. G. W. Tookey. *South Midland Group:* Friday, January 23, 7.30 p.m., Technical College, Luton. "Submersible Pumps and Motors," by Mr. W. L. Gardiner.

WAR-TIME SHIP REPAIRS.

(*For Description, see Page 69.*)

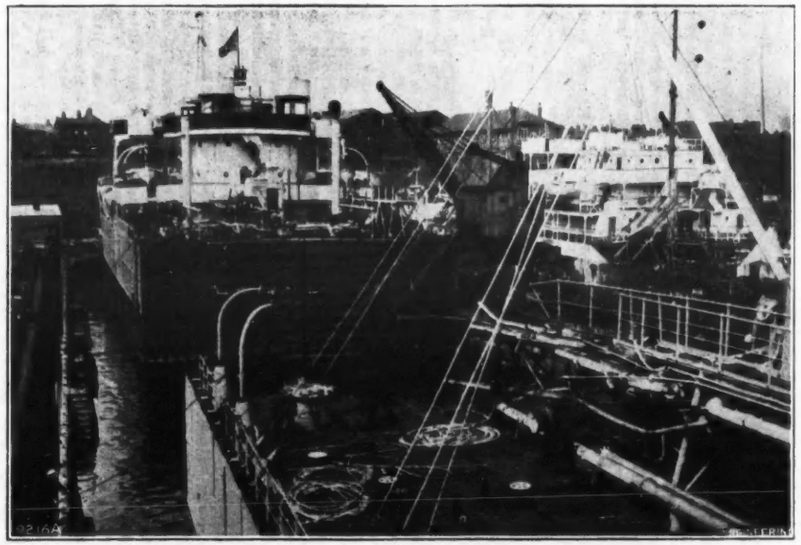


FIG. 1. TWO HALVES OF TANKER "THORSHOVDI" DOCKED.

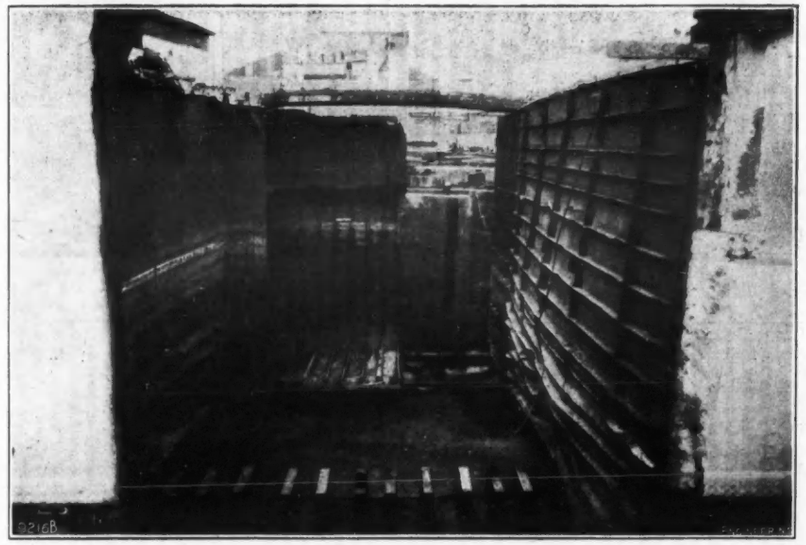


FIG. 2. GAP BETWEEN TWO HALVES OF "THORSHOVDI" IN DOCK.

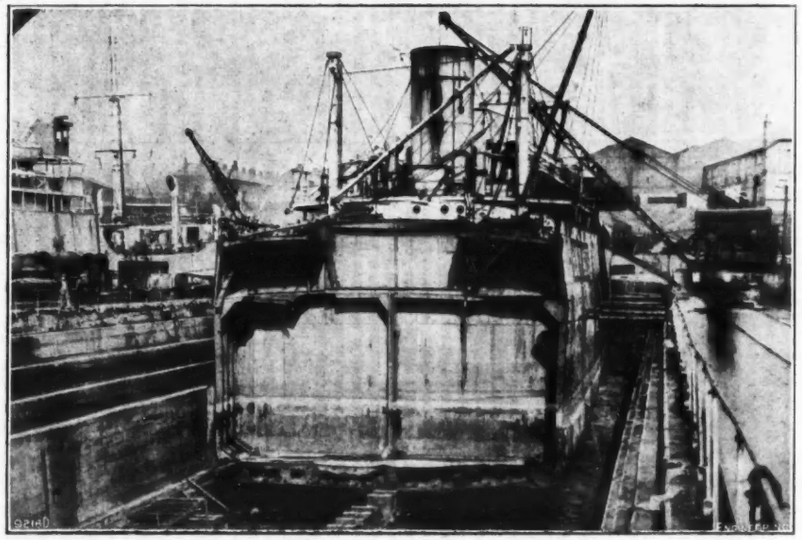


FIG. 3. AFTER HALF OF "HARPAGUS" IN DOCK.

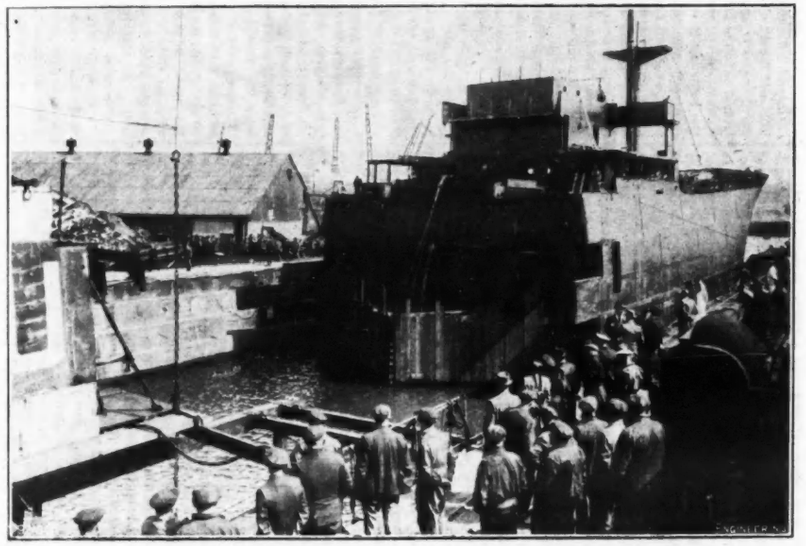


FIG. 4. NEW FORE END OF "HARPAGUS" ENTERING DOCK.

ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

Telegraphic Address:
"ENGINEERING," LESQUARE, LONDON.

Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

SUBSCRIPTIONS.

"ENGINEERING" may be ordered from any newsagent in town or country and from railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months (or for six or three months, *pro rata*), payable in advance:—

For the United Kingdom and all places abroad, with the exception of Canada	£4 10 0
For Canada	£4 5 0

Subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, mentioning the agent's name and address.

ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for insets, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 8*s.* for the first four lines or under, and 2*s.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 24*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years

CONTENTS.

	PAGE
Intermeshing Non-Circular Algebraic Gears (*Illus.*)	49
Literature.—Annual Report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington. Fault Localizing and Testing on Electric Mains	52
Brittle Fracture in Mild-Steel Plates—II. (*Illus.*)	53
Continental Electrical-Instrument Practice	54
Diesel Engines Underground (*Illus.*)	54
The Nelson Research Laboratories of the English Electric Company (*Illus.*)	56
Portable Water-Level Recorder	58
British Standard Specifications	58
Books Received	58
Personal	58
Notes from the North	59
Notes from South Yorkshire	59
Notes from Cleveland and the Northern Counties	59
Notes from the South-West	59
Notices of Meetings	59
The Peace-Time Navy	61
Heavy-Oil Engine Working Costs	62
Notes	63
Letters to the Editor.—Age and the Engineer. Engineering Units of Force	63
Obituary.—Mr. R. K. Pierson, C.B.E. Mr. G. R. Sharpley	64
The Engineering Outlook—III.	65
Floating Compressed-Air Plant	68
Labour Notes	68
Some War-Time Ship Repairs (*Illus.*)	69
Notes on New Books	72
"ENGINEERING" Patent Record (*Illus.*)	72

ENGINEERING

FRIDAY, JANUARY 16, 1948.

VOL. 165. No. 4277.

THE PEACE-TIME NAVY.

THE tendency of history to repeat itself has been remarked on many occasions; also the fact that, as one observer shrewdly commented, "Every time that history repeats itself, the price goes up." In no aspect of the nation's affairs are these axioms more evident upon thoughtful comparison than in the sphere of defence, and especially naval preparedness; yet in none are the lessons of the past more frequently minimised, and sometimes ignored, under the stress of more immediate preoccupations. To use a homely parallel: a year ago, the man in the street could talk of nothing but the shortage of coal; now that he has a lack of potatoes to occupy his mind, and the weather happens to be mild, coal, as a topic of conversation, has practically ceased to claim his attention. It may be that a capacity to worry about only one thing at a time has advantages in some respects—it may even be that the growth and long-continued stability of Britain owes a great deal to an inability of the average British mind to see difficulties and dangers in their true proportions; but it is not safe to assume that, because admitted shortcomings have not proved fatal yet, they are acceptable as a basis of policy.

Fifteen years ago, the British Navy had been pared to the barest minimum and everyone knew it. Ten years ago, a good start had been made to restore it to a proper strength, though most of the additional ships were still on the stocks or only on paper. Five years ago, in spite of heavy losses, the Navy was very much a force to be reckoned with, and assurances were being freely given and accepted that never again would its strength be reduced to the absurdly inadequate level of the inter-war years. Three months ago, although it was common knowledge that some hundreds of ships had been scrapped, earmarked for scrapping, or disposed of to other navies, no particular public concern was felt on that score until, without any warning, there came the announcement that the Home Fleet had been reduced to an immediately effective strength of one cruiser and four destroyers.

A couple of days later—incidentally, on Trafalgar Day, though no one seems to have remarked upon the ironic conjunction at the time—Mr. Anthony Eden raised the matter in the House of Commons, in the debate on the King's Address; even after the increased cut in naval man-power, he pointed out, the Navy would still have a strength of 140,000 in March, 1948, which should enable more ships to be kept at sea if the available personnel were properly used. He asked for an assurance that the fleet reductions were no more than "temporary, even transitional, and that research, development and training are continuing so that a strong modern Fleet may be once again at sea." Then he added, referring to the Minister of Defence (Mr. A. V. Alexander), "I am sure that the right honourable gentleman would be the last to forget that this nation cannot afford once again to undergo the race against time which we had during the first year of the last war; the next race will be very much shorter." Later in the debate, the Prime Minister sought to minimise the gravity of the position disclosed, emphasising that the reductions of operational strength represented no more than "some degree of temporary immobility."

Later, on October 23, the Minister of Defence made a statement on the subject, admitting the "temporary immobilisation," but emphasising that "this term 'immobilisation' should not be misunderstood." He assured the House that the actual strength of the Home Fleet, when the order for the reduction was given, was one battleship, five cruisers and 12 destroyers, "apart from the very large training squadrons, including battleships, destroyers, frigates and others, which remain in being"; and described the one cruiser and four Battle-class destroyers which were still immediately operational as "an emergency striking force during this temporary period of readjustment." Pressed by Mr. Winston Churchill to publish details of all the ships in commission, and the scale of their complements, Mr. Alexander pleaded the need for "security measures"; and, on a subsequent occasion, extended this to the point of declining to publish figures of the strength of the fleets in various waters. Evidently, however, many Members were gravely dissatisfied, as was shown clearly on October 28, in the debate on an amendment to the Address, criticising the Government's defence policy.

The whole affair must have appealed with peculiar significance to any member of Parliament or of the general public who had read the second volume of the autobiography* of Admiral of the Fleet Lord Chatfield; especially since, although the book had then been published only a few weeks, it was written in 1940. Whether the title also dates from 1940, Lord Chatfield does not say, but the history of British naval policy has repeated itself so often that this may be so, though there can be little enough satisfaction in having such an uneasy prognostication fulfilled after such a short lapse of time. His own Service career spans several of these recurrent crises; though they are not peculiar to the present century, as was well brought out by Vice-Admiral L. V. Morgan in his paper on "Portsmouth Dockyard in relation to Naval Policy," presented before the Institution of Naval Architects in September last and reprinted, in abridged form, on page 414 of the previous volume of ENGINEERING. Always, it seems, a hard-fought war has been followed by a period of excessive retrenchment; usually, no doubt, because financial difficulties resulting from the war reinforced the natural, if wishful, thought that another war in the immediate future was improbable. It may be observed of the present circumstances, however, that never before, so far as we can recollect, has this state of affairs coincided with such a widespread relinquishment of actual and potential bases in distant waters. The lack of the Navy's former bases in Eire had an effect upon naval operations in the Western Approaches, during the recent war, that should not be too quickly forgotten; even when allowance is made for the role of aircraft in commerce protection, the loss of the ports on the southern coast of Ireland was a serious and costly deprivation.

Lord Chatfield's book is not confined to naval affairs, as it covers also the various Government appointments which he held after retiring from the position of First Sea Lord in August, 1938; first,

* *It Might Happen Again*, by Admiral of the Fleet Lord Chatfield. William Heinemann, Limited, 99, Great Russell-street, London, W.C.1. [Price 18*s.* net.]

on an official mission to India, to investigate the problems of Indian defence, and subsequently in the Cabinet, as Minister for the Co-ordination of Defence. The Navy, however, is the chief concern of the book, as it has been of the author throughout his life, and it is chiefly for the sake of his inside knowledge of naval needs and policy, and his thoughtful and experienced judgments, that his autobiography should be read now and will be studied in years to come. His comments are often pungent, but they are never bitter; indeed, in addition to some rather unexpected tributes to political figures with whom his official positions brought him into contact, he is at pains to explain, in more than one instance, how they were impelled by circumstances to take decisions that were at variance with his own deep-seated convictions.

In conclusion, he lays down five principles which, in his view, should form the basis of national defence policy. They are best quoted *in extenso*. Firstly, he says, "Peace strength must be fixed in accord with the organised power to recover to war strength" and "it must be related to the strength of the principal Powers and in accordance with our geographical position as an Empire." Secondly, the fact should be borne constantly in mind that "Strength can only be changed very slowly, so it must be based on a national defence policy, which looks well ahead; the policy should not change with changes of Government, and the national safety should be independent of party politics." Thirdly, "the safety of the country should be a first charge on finance." Fourthly, "the three arms of defence being interdependent, their annual estimates should be presented to Parliament in a combined form, after examination by the Committee of Imperial Defence and approval by the Cabinet"; and, finally, "foreign policy must be in accord with actual national strength." Some of these principles, as Lord Chatfield admits, were recognised in the White Paper on *Central Organisation for Defence* (Cmd. 6923), issued some 18 months ago, but the policy there outlined was framed on a national rather than an Empire basis, it did not place defence policy on a plane above party politics, and emphatically it did not make the national safety "a first charge on finance."

That the research work mentioned by Mr. Eden is continuing is generally known; for instance, the existence and principal members of the staff of the Admiralty's Scientific Research and Development Department, and those of the corresponding departments in the Air Ministry and the Ministry of Supply, are indicated in public sources of reference—even though the *Navy List* is still a confidential document. So far as up-to-date scientific knowledge is concerned, it may be assumed that this country is as well informed as any other; the crux of the problem lies in the time required to produce the material embodying that knowledge and to train the necessary personnel in its use, the financial outlay involved, and the competing claims of other occupations upon the available man-power. To bring these conflicting demands into what he regards as the proper perspective is the main purpose in Lord Chatfield's book. That his views will be regarded as controversial in time of peace is inevitable, but there is no denying the knowledge, experience and sincerity that inspires them. On the material side, the matter is fundamentally one of engineering design and production, taking the term "engineering" in its widest sense. In the other respects, cost and manpower, as he observes in conclusion, it is one of educating public and legislative opinion to an appreciation of the essential facts that "navies cannot be built in a day, nor can the highly skilled personnel who have to use and maintain complicated modern material be produced by a wish. The idea that sea power can be developed rapidly by merely voting money at a convenient time is . . . unworthy of a nation that has had centuries of naval experience and lessons." Some few (there are always such in peace time) may consider his views on sea power to be as outmoded, in the light of modern developments, as the sail training which, as First Sea Lord, he successfully opposed; but they would be well advised to read his book, and to study its background carefully, before condemning them out of hand.

HEAVY-OIL ENGINE WORKING COSTS.

THE recently-published report on Heavy-Oil Engine Working Costs, prepared by the Diesel Engine Users' Association for the year 1945-46, shows clearly that the rate of fuel-oil consumption, in terms of weight consumed per unit generated, does not increase under operating conditions with the increasing age of the individual installations but, in fact, remains sensibly constant. Indeed, according to one of the tables included in the earlier portion of the report, the general average in the period 1922-1930 for the stations then under consideration was found to be 0·708 to 0·748 lb. per unit generated, while in the period 1940-1946, the highest yearly average was 0·625 lb. and the lowest (1946) 0·608 lb. a considerable difference in the right direction. Without doubt, the generally higher efficiency of the gradually increasing proportion of engines using mechanical fuel injection is accountable in some measure for this result; but, apart from this, it is interesting to see that the various members of the D.E.U.A. manage to maintain their respective plants in such excellent condition, despite the difficulties of the times. The table referred to gives the average of between 40 and 50 separate stations, each consisting of several individual plant units, and it is of further interest that the "running plant load factor" is from 60 to 65 per cent. of the full-load rating of all these units, without much change year by year.

The members of the Committee responsible for the production of this valuable annual report not only pay attention to the fuel-oil consumption, but also include information about the rate of lubricating-oil consumption. In earlier years, the standard was established of comparing this on the basis of 2,380 rated brake horse-power hours per gallon. This has been exceeded by no fewer than 39 stations in 1945-6 and one station claims that as many as 9,850 brake horse-power hours have been achieved; this is for a waterworks' pumping plant. The runner-up, another water-pumping station, reports 7,200 and third place is claimed at 6,680 brake horse-power hours per gallon by an industrial Diesel-electric installation. A second, and probably a more useful, basis for comparing the rate of lubricating-oil consumption is to express it as a ratio to the fuel-oil consumption. Figures in the report enable this to be appreciated and, on this comparison, it is interesting to note that the same pumping stations—which may be referred to as Nos. 1 and 2 on the brake horse power-hour basis, still head the list; but No. 2 becomes No. 1, with 260 lb. of fuel oil per pound of lubricating oil, and No. 1 becomes No. 2 with 213 lb. per pound.

These represent the best that operators of mechanical-injection engines were able to achieve with modern methods of reconditioning and filtering the oil. In general accord with expectation, these figures are not reached by engines working for short periods at a time, nor by those of ancient lineage. With one installation of air-blast injection engines, used for illumination, etc., in a large store, while being able to claim 3,330 brake horse-power hours per gallon, it appears that, on the fuel to lubricating oil basis, it is no better than 101 to 1. Some other stations evidently are not doing well, as the average figure for 58 stations is as low as 72 to 1 on this basis

The general measure of improvement as regards lubrication methods is well brought out by comparing the similar periods already alluded to in connection with the rate of fuel-oil consumption; thus, in the period 1922-1930, the average number of brake horse-power hours per gallon for all stations was of the order of 1,400, while, in the period 1940-1946, the figure increased from 2,120 in 1940 to 2,500 in 1946, for approximately the same number of stations, though not necessarily the same individual stations.

General averages cannot well represent any but very rough comparisons, because of the varying operating conditions applicable to the individual stations; for example, one of the stations, containing only the mechanical-injection type of engine, operating 8,760 hours a year, records an overall cost of 3·101*d.* per unit generated, whereas another records a total operating cost of only 0·539*d.* per unit. In the one, the cost of wages represents 1·610*d.* per unit, while, in the other, wages account for only 0·017*d.* per unit. This great variation is explained by the fact that, in the more efficient station, two engines generated over 5½ million units during the year, while the less efficient station generated less than 390,000 units with three engines. Obviously, the annual cost of the individual staff wages would have been similar if the local demand had been such as to reduce the proportionate cost for wages on the unit-generated basis. This system of comparison must also have regard, therefore, especially for overseas stations, to the relative costs of European and native labour.

The relative costs of fuel and lubricating oil in various districts must be considered likewise. In one home station, the cost of fuel oil is given as 157*s.* per ton, while ten others in the same table average about 200*s.* per ton. On the basis of units generated, the station with the lower fuel cost records the figure 0·571*d.* per unit for both fuel and lubricant, while the ten others varied between 0·633*d.* and 0·790*d.* per unit on the same basis, compared with the general average for fuel and oil of 0·696*d.* per unit for the 11 engines in the aggregate. Perhaps some explanation of the difference in fuel cost can be deduced from the fact that the less costly fuel and lubricant figures relate to the plant of London and Thames Haven Oil Wharves, Limited. Another reason why the general averages recorded do not reflect actual facts is that, in some cases, the cost of stores, water, wages and repairs, and maintenance, are not completely recorded, and, consequently, cannot be taken into account.

The recorded annual costs pertaining to waterworks pumping stations are interesting to correlate, but one of these claims a performance which can hardly be accepted; this records that 0·406 lb. of fuel oil was used per water horse-power per hour. It is difficult to believe that the pumping plant was nearly as efficient as this represents. In eight other waterworks pumping plants, the fuel used is stated to vary from 0·457 lb. to 0·692 lb. per water horse-power per hour. On the supposition that normal operating conditions enable one brake horse-power to be developed for 0·39 lb. of fuel, this means that the efficiency of the pumps varies from 86 per cent. to 56·5 per cent. Thus it would appear that the figures given for gear-driven reciprocating well pumps, claiming the consumption of only 0·406 lb. of fuel per water horse-power per hour, even at, say, 90 per cent. pump efficiency, would be equivalent to 0·365 lb. per brake horse-power as an average of two sets working 8,649 hours annually—practically without a stop. This demands either corroboration or amendment.

One of the most interesting of the tabulated sections of the D.E.U.A. report is that giving technical details of engine performance. In this, the totals of running hours since installation are given for individual engines in each of 39 named installations, together with particulars of engines, with cylinder dimensions, revolutions per minute, brake mean pressure at rated load, diameter and clearances of bearings, and rate of wear of cast-iron cylinder liners with various finishes (honed, ground, or machined). There are many other columns, recording wear, etc., in hours of operation, coolant methods, and exhaust systems, the whole presenting a really comprehensive review of all practical details. The final column is headed "What has caused most trouble?" but it is not clear why this particular wording has been adopted; the records themselves show a regularity of operation that proves almost complete immunity from trouble. Most of the entries under this heading refer to compressor trouble in the old type of air-blast injection engines; some cracked pistons and cylinder heads are recorded, and a few other entries refer to water-cooling systems and lubrication. On the whole, this section presents a very fair statement of substantial reliability, and explains why such good working results mentioned in other sections of the report have been so generally achieved. It is gratifying to note that a very creditable attempt has been made in the present report to keep the various tables to a more or less standard size when folded.

NOTES.

LONDON TRANSPORT IMPROVEMENT PLANS.

LORD LATHAM, chairman of the London Transport Executive, revealed plans for improving road and rail passenger transport, at a Press conference on January 12, 1948. He said that deferred maintenance, renewals and extensions would be dealt with, and they had to cater for an increased demand; the individual Londoner was travelling a fifth more than he did before the war. During the war, factory space had been given up, and in 1947, which had been the most difficult year, more than half the 'buses were over replacement age. Nevertheless, the 'buses, trams, coaches and trains ran 610,000,000 miles, 31,000,000 miles more than in 1946, and a record in the history of London Transport. The services, however, were still insufficient, and in addition to devising their own plans, they were always ready to accept suggestions from members of the public. The elimination of queues, which were largely due to shortage of 'buses, was their first aim for 1948. They had on order 4,000 'buses, and it was hoped to receive 1,200 of them this year. The plan for the improvement of 'bus services was in three stages: to replace worn-out 'buses, to strengthen existing services, and to open up new routes and extend existing routes. The present fleet of 'buses numbered 9,000, and 500 more were required, apart from replacements. It was hoped to introduce a wider 'bus in 1948—8 ft. wide instead of 7 ft. 6 in. —and the seats and gangways would consequently be more comfortable. Owing to the slowing down of manufacture of new 'buses, it was unfortunately necessary to defer the abolition of the South London trams, by perhaps five years. Referring to the railways, Lord Latham said that the Central Line would be extended farther east and west during the year, and bottlenecks on the Metropolitan Line at Harrow-on-the-Hill and Preston Road would be eliminated. A broadcasting system would be installed in the booking offices of all stations, and by this means, information on traffic delays, sudden frost, crowds, etc., would be transmitted to the staff from Central Traffic Control. The system would also enable any member of the staff to dial a number and receive a repetition of the recorded message. During 1948, a telephone system connecting the driver of a train stopped in a tunnel to Central Control would also be established. By the end of the year, all lines would be equipped with anti-freeze liquid distributors for conductor rails, which were described on page 479 of our previous volume. Additional escalators would be installed at Holborn, Chancery Lane and Liverpool Street. There were 143 new underground cars on order, and the installation of welded half-mile lengths of rail would be continued until all tracks had been relaid. London Transport had recently been granted a licence to use short-wave wireless experimentally. A central station working on 77·2 megacycles was to be installed at Earls Court, and the system would be used by London Transport engineers for communicating with each other, for demanding tools and materials to be sent to a construction job, etc. Lord Latham concluded his review of future developments with a reference to proposed improvements in staff amenities.

STEEL PROSPECTS IN 1948.

The achievements of the British steel industry during the past year were described by the Chancellor of the Exchequer (the Rt. Hon. Sir Stafford Cripps) in a statement which he made on Monday last. At the same time, he expressed the hope that output would be even higher during 1948 and indicated the possibility that larger supplies might be allotted to a number of industries. The output for 1947, he said, was some 12,700,000 ingot tons, or about the same as in 1946, compared with the estimate of 13,750,000 tons, which had been made on the assumption that all the conditions would be favourable. During the last two and a half months, however, production had risen to a level equivalent to 14,250,000 tons per annum, and the target for 1948 had therefore been fixed at 14,000,000 ingot tons. Such an output, which would be a record in the history of the industry, was within its technical capacity. Indeed, the chief limiting factor was the supply of raw materials, as 12,000,000 tons of coking coal would be needed and the scrap position was not free from anxiety, owing to the depletion of stocks. Even so, we should still experience a severe shortage owing to the unprecedentedly high demand and the fact that imports could not be expected to exceed some 500,000 tons. This 14,500,000 tons of ingot steel would produce 10,500,000 tons of finished steel, and of the latter amount it was proposed to export 1,000,000 tons, leaving only 9,500,000 tons to meet the effective home demand. This compared with the actual total of 8,000,000 tons which was available in 1947 and represented a shortage of one million tons when what was needed for essential purposes was taken into account. While, therefore, the Chancellor said, the engineering, vehicle and consumer industries would be allocated rather more than last year, and much more would be available for agricultural, mining and electrical machinery, it would be necessary to make a considerable reduction in the amounts allowed for building and shipbuilding, and a smaller reduction would also have to be imposed on the gas industry. These figures would, of course, have to be revised if there were any shortage in production. On the other hand, there might be an opportunity for expansion by bringing the general average of the plant nearer the highest level of efficiency.

CONTRA-FLOW HEAT EXCHANGERS.

A paper on the "Design of Contra-flow Heat Exchangers" was read by Professor Ernst Schmidt, Dr. Ing., M.I.Mech.E., before the Institution of Mechanical Engineers, on Friday, January 9, 1948, at an extra general meeting held in conjunction with the Applied Mechanics Group. Dr. S. Livingstone Smith, member of council, was in the chair. The author remarked that, in the design of heat exchangers, it was often considered sufficient to achieve the required output, while ignoring the weight and energy involved. These factors could not be ignored, however, when designing heat exchangers for transmitting heat from the hot gases leaving an aircraft gas turbine to the compressed air, before its entry to the combustion chamber. Professor Schmidt developed formulæ for determining the main dimensions of an exchanger, for gases at turbulent flow, in terms of the intended heat exchange, the total drop of temperature, the total loss of energy, and the properties of the fluid. He used the analogy between heat transfer and friction, and introduced another non-dimensional heat-transfer coefficient, which he suggested could be used with advantage, instead of the Nusselt number, for describing heat transfer in tubes, and for similar problems. In the development of the formulæ, which give the conditions of minimum weight and minimum volume, it was shown that the weight and total volume of the heat exchanger depend on the ratio of temperature drop and loss of energy on both sides of the heat-exchanging surface. Some curves were given in the paper to facilitate the application of the formulæ. Professor O. A. Saunders, D.Sc. (Eng.), M.I.Mech.E., in opening the discussion, remarked that the formulæ might have been derived from two well-known basic equations of friction and heat transfer in pipes: the equation for the friction in turbulent flow in a pipe, and the well-known form of the Reynolds analogy between heat transfer and friction. Taking the five variables in the problem, he showed how the author's formulæ could be derived very simply from the two basic formulæ. Professor Saunders drew attention to certain factors which had been ignored, particularly the author's neglect of the weight of the end plates of the tube nest, and the weight and volume of the ducts. Mr. W. F. Cope, M.A., A.M.I.Mech.E., considered it necessary to re-state the definitions of the Reynolds number, the Prandtl number, the Nusselt number, and the Stanton number; the latter number had been referred to by that name for many years, although the author had said that it "should, perhaps, have a special notation." Major C. E. Iliffe, R.E.M.E., M.A., A.M.I.Mech.E., referred, *inter alia*, to the fact that strict contra-flow conditions did not occur over the whole length of the tubes, and he therefore presumed that the length used in the formulæ signified an effective length, not the actual length. Several other speakers took part in the discussion.

LETTERS TO THE EDITOR.

AGE AND THE ENGINEER.

TO THE EDITOR OF ENGINEERING.

SIR,—The problem of the ageing engineer is brought sharply home by the Institution of Mechanical Engineers in a recent appeal for contributions to the Benevolent Fund. In a circular letter from the President, the following significant paragraph occurs: "At the present time there is evidence especially of the increasing distress among a very deserving section of our fellow members, arising from the war itself and the disturbed conditions which have followed, this being particularly marked among those past middle age."

It is an old saying that "Youth must be served." This maxim is true in other walks of life than boxing, where it probably originated, though it is equally true that in industry—and the engineering profession is no exception to the rule—the younger man's ability frequently misses its reward because the path is blocked by an older man who, knowing that his chances of employment elsewhere are rapidly becoming slender, is neither inclined to encourage a potential rival, nor to take the chances that the younger man would have taken. The result is that the older executive plays for safety, the younger man is disheartened, and directors are torn between the alternatives of discharging an old employee who has given them long and faithful service, or of seeing progress stifled. The result is seen to-day in the fact that no firm wants to employ an engineer who has passed the age of 40, unless he is already in their employ; and no older man, applying for employment in an executive position, has much chance of getting it. The problem is seen most clearly defined in the case of those who volunteered for service in the war and, for one reason or another, were not taken back by their former employers. It is to be feared, too, that, in the case of the older civilians who held Government war-time posts, the latent dislike of the industrialist for officialdom loads the scales against the man who comes from a Government department. In considering the problem of re-employment after the war, reference may be made to an article which appeared recently in the *Strand Magazine*. The author of the article investigated results obtained by ex-Service seekers for employment by the simple expedient of answering their advertisements and asking them for their experiences. Among other facts that were forthcoming was that results obtained from the official Government bureaux were negligible.

Benevolent funds can do no more than alleviate the troubles of a fraction of the older men who have been displaced by the younger; what, therefore, is to become of the older men, those whom the President of the Institution of Mechanical Engineers refers to as "past middle age"? The position in itself is not simplified by classifying "Unemployability" simply on the basis of years; some men become senile in their forties, while others, like the late Colonel R. E. B. Crompton, retain their mental faculties until four score years have passed. The writer, who pleads guilty to having passed his 64th birthday, and who, on both sides of the family, is descended from persistent octogenarians who retained their mental and physical powers until their death beds, takes no pleasure in the thought that, after a life spent in most branches of heavy engineering, and which culminated in the holding of His Majesty's commission as an engineer officer, R.N.V.R., he has now nothing before him but the prospect of about 20 years of life with no technical problems to employ his mind because, forsooth, he has reached an arbitrary age limit at which, according to present-day ruling, he is already at least 20 years gone in senility.

His own suggestion for an outlet for a portion of the older men is that some of the less exacting research appointments should be filled, not from the ranks of young men fresh from the universities, but by older men, displaced from industry by the slogan that "Youth will be served." This proposal, when put to a predominately youthful audience, was received almost with consternation; for, it would appear, research appointments are

regarded as tit-bits for the good boys of the universities, whereas they should be looked upon with horror by those students as cramping and soul-destroying. How long will the need for practical training, among the men who make things, be counted as of small moment by university authorities?

It is true that the highest form of research worker is born; that some draughtsmen are such born engineers that, without any practical experience in the shops, they can produce designs in which nuts can be tightened as readily with a spanner as with the pencil; and that some men can never gain the rudiments of how to control their fellow engineers, however many years they spend in the shops. In the main, however, the young engineer can only be half an engineer at most, if he lacks practical ability or experience. It is for that reason that the average young research hand who lacks the flame of genius that makes a Rutherford or a Parsons, should shun a research appointment like the plague. Incidentally, Parsons is a bad example to cite, as he was, above all else, a thoroughly practical man by training and instinct.

Not infrequently—though certainly not invariably—as years increase, the mind tends to become more selective, and more acute on fewer subjects; we tend, in fact, "to know more and more about less and less." This should make us better research workers; of the type, admittedly, who must do the detail work for others, but even on detail work our brains would be employed and we should be contented. The word "research" covers a very wide field, and cannot be confined to the subjects which figure so largely in the proceeding of engineering institutions; but, even in that class of research, it would seem that a great deal of the work that one can best describe as "fetching and carrying" is well within the scope of the older man. To use young engineers for this work is to cramp minds that should be expanding.

The time has come, I submit, to institute some research into the problem of how best, in times of labour shortage, to take advantage of the potential ability possessed by the men whose age now excludes them from consideration in "Situations Vacant" advertisements; and the first investigation should be into the reason why the market value of an experienced man declines so rapidly when he passes the age of 40.

Yours faithfully,

January 8, 1948. RESERVIST.

ENGINEERING UNITS OF FORCE.

TO THE EDITOR OF ENGINEERING.

SIR,—In response to the request from Mr. Lennie, in his letter published in your issue of January 9, on page 40, I give below the argument that convinces me of the value of the name "slug" applied to a unit of mass. My views on this matter crystallised many years ago when I had the task of explaining to students how to get the right answers to problems in engineering dynamics. There the necessities seemed to be: (*a*) not to conflict with everyday terminology; (*b*) not to use the same term for different things; and (*c*) to give simple calculation methods that can be applied without hesitation.

In engineering, the unit "pound" invariably means the gravitational force on the piece of metal recognised in commerce and elsewhere as a "one-pound weight." The simplest expression of the relation between force, mass and acceleration is $F = m\,a$. With F expressed in pounds, and a in ft. per second per second, the fact that a one-pound weight falling freely under the action of gravity has $a = 32{\cdot}2$, shows that its m must be $\frac{1}{32{\cdot}2}$. Therefore, if it is desired to keep the dynamical equation in its simplest form (*i.e.*, without a numerical constant) the unit of mass is that of 32·2 pounds weight. For convenience, a name is required for this unit, and "slug" already having been invented for the purpose, it is natural to use it.

For calculation purposes one remembers that a slug is bigger than a one-pound weight, and that the ratio between them is 32·2 and the correct value of m to be used in any specific problem is then immediately apparent. All this is strictly utilitarian and no doubt pedantic arguments against it can easily be devised, but not one of those ascribed by Mr. Lennie to the late Dr. F. W. Lanchester seems to me to have any importance at all. The use of the term "gravitational unit" for this unit of mass is most undesirable; firstly, because the mass of a piece of machinery has nothing to do with gravity, and secondly, because the term is long and awkward and gives the impression that the quantity concerned is so doubtful that no precise name exists for it. If there is any "gravitational unit" in common use, it is the pound unit of force.

Yours faithfully,

W. A. TUPLIN, D.Sc.

Head of Engineering Research and Development David Brown and Sons (Huddersfield) Ltd.

Huddersfield, January 12, 1948.

OBITUARY.

MR. R. K. PIERSON, C.B.E.

IT is with regret that we record the death of Mr. Reginald Kirshaw Pierson, which occurred, after a long illness, at his home, Manor Cottage, Smithwood Common, Cranleigh, Surrey, on January 10. Mr. Pierson, who was chief engineer of the Aircraft Section of Messrs. Vickers-Armstrongs Limited, with which firm he spent the whole of his working life, was the son of the Rev. K. T. Pierson and was born in Norfolk on February 9, 1891. He received his general education at Felsted School, Essex, and in 1908, when seventeen years of age, became a pupil apprentice in the Erith Works of Messrs. Vickers Limited. On the completion of his pupilage in 1911, he joined the newly-formed aircraft section of the firm and was appointed assistant to Mr. A. R. Low, then aeroplane designer to Messrs. Vickers Limited. The subsequent two years were spent on work connected with the determination of stresses and strains on aeroplane wings, fuselages and other component parts of aircraft, and the balancing of aeroplane engines. Meanwhile he continued his engineering studies at Erith Technical Institute, and, in 1912, obtained the B.Sc. (Eng.) degree of London University. He also learned to fly, and, in 1913, received pilot's certificate No. 660 of the Fédération Aéronautique Internationale, British Empire Section.

When war broke out in 1914, Mr. Pierson's work on the calculation of stability performance and other matters connected with the design of aeroplanes and of airscrews became much intensified. In 1915, he was appointed assistant aeroplane designer and in 1917 became chief designer to his firm, which became known as Vickers (Aviation) Limited. He was the designer of the famous Vickers Vimy Rolls-Royce twin-engined aeroplane, which was intended for bombing operations, but, owing to the supervention of the Armistice in November, 1918, the machine was never used on such service. This aircraft, however, when modified for commercial use, was that employed by Sir John Alcock and Sir Arthur Whitten Brown for the first trans-Atlantic flight from Newfoundland to Clifden, Ireland, on June 14 and 15, 1919. Later in the same year, a Vimy aircraft was flown to Australia by Air Commodore C. E. Kingsford-Smith, and subsequently another machine of this type was flown to South Africa. Other world's record aircraft of Mr. Pierson's design include the Vickers Vespa, which won the altitude record in 1932 and the Wellesley, which established the long-distance record of 7,162 miles non-stop in 1938. Well-known Royal Air Force types of Vickers aircraft designed by Mr. Pierson were the Virginia twin-engined bomber and the Victoria troop-carrying machine, with the aid of which the R.A.F. successfully carried out the evacuation of the whole of the civil population of Kabul in 1929. Other types included the Vildebeest torpedo bomber and the Vincent general-purpose biplane. The latter was followed by the famous Wellington twin-engined bombing aeroplane which was in production at the outbreak of the recent war, and continued to be built until the cessation of hostilities. The Warwick air-sea rescue machine was another type which was much used by Coastal Command.

Mr. Pierson was appointed chief engineer of the Aircraft Section of Messrs. Vickers-Armstrongs Limited on September 1, 1945, after having occupied the position of chief designer for 28 years. He was a special director of Messrs. Vickers-Armstrongs Limited. For his services in the war of 1914-18 he was made an M.B.E., and was created a C.B.E. in 1943. He was elected an associate fellow of the Royal Aeronautical Society in 1913, and an associate member of the Institution of Civil Engineers in 1917. He was elected a Fellow of the Royal Aeronautical Society in 1926 and served on the Council and on various sub-committees, including those dealing with grading and with lectures, for a number of years. He was responsible for two papers published in the *Journal* of the Society, namely, "The Use of the Wind Tunnel in the Prediction of Aeroplane Performance" (February, 1928) and "Design Factors of Civil Aircraft Affecting Operating Costs" (January, 1945).

MR. G. R. SHARPLEY.

WE also note with regret the death of Mr. George Ruston Sharpley, which occurred at his home in Lincoln on January 11, less than a fortnight after being taken ill on the eve of starting on a business trip to America, Australia and New Zealand. Mr. Sharpley, who was in his 77th year, was chairman of Messrs. Ruston and Hornsby, Limited, Lincoln, with which firm he had been associated for 60 years. He was the son of Mr. Henry Sharpley, farmer, of Limber, Lincolnshire, and a nephew of Mr. Joseph Ruston, founder of the firm of Messrs. Ruston and Hornsby, and became an apprentice in his uncle's works at the age of 16. At that time, the site of the present Ruston boiler works was a farm, and the firm were building four- and six-wheel locomotives and turning out excavators at the rate of three a fortnight for the Manchester Ship Canal, which was then under construction. At the age of 23, Mr. Sharpley was appointed works manager, and, in 1918, on the amalgamation of his firm with Messrs. Richard Hornsby and Sons, Limited, Grantham and Stockport, he became joint managing director with Mr. David Roberts. Two years later he became sole managing director. He relinquished this position in December, 1943, after occupying it for some 25 years. Mr. Sharpley was elected chairman in 1939, in succession to the late Colonel J. S. Ruston.

Starting in his early days on the manufacture of steam engines, portable engines and agricultural machinery, Mr. Sharpley later passed on to the construction of oil engines. He was responsible for the production of some of the first oil engines made by his firm, and experienced the early "teething troubles" in the development of this power unit. He took a keen interest in the transition from the early slow-speed horizontal type to the present high-speed type of oil engine for industrial and marine purposes, and paid particular attention to new methods and costs of production. In 1928, he undertook a world tour to study market conditions overseas, and was away from this country for about nine months. Mr. Sharpley joined the Institution of Mechanical Engineers in 1893 as a graduate, was elected an associate member in 1897, and transferred to the class of member in 1900. In addition to being chairman of Messrs. Ruston and Hornsby, he was vice-chairman of Messrs. Ruston-Bucyrus, Limited, Lincoln, chairman of Messrs. Davey, Paxman and Company, Limited, Colchester, and a director of Messrs. Ransomes, Sims and Jefferies, Limited, Ipswich, and of Messrs. Ruston and Hornsby Australia (Pty.), Limited. He was appointed a Justice of the Peace for Lincoln in 1916 and served as City Sheriff in 1946.

JUBILEE OF VENESTA LIMITED.—Yesterday, January 15, was the 50th anniversary of the formation of the plywood-manufacturing firm of Venesta Limited, Vintry House, Queen-street Place, London, E.C.4, who have marked the occasion by the publication of an attractive brochure recounting the story of *Our First Fifty Years*. Originally formed to make tea chests and their lead linings, the firm now produce, in addition, metal-faced plywood, collapsible metal tubes, and aluminium foil.

THE ENGINEERING OUTLOOK.

III.—THE MANPOWER SITUATION.

DURING 1947, there have been few outward signs of major labour problems concerning the engineering industry. Stoppages have been few and minor in character; from January to October, only 107,000 working days were lost in disputes, compared with 297,000 days during the corresponding period in 1946. There have been no union claims for higher wages, but earnings have increased and the average number of hours worked has fallen. The productivity of labour cannot be measured statistically for want of data, but, from the production and labour figures available for certain sections of the industry and from numerous statements made by managements, it is clear that the output per man is still appreciably lower than pre-war. Of all the principal factors governing the efficiency of engineering production—a regular and adequate supply of fuel, materials and components; availability of the required classes of man-power; a low labour turnover; efficient and understanding management; good labour discipline and the will to work—the failure of fuel supplies last winter, and the constant shortage and uneven flow of materials and components have been by far the most important causes of low output per man. Few engineering concerns were able to provide their employees with steady work, and it is no secret that many large companies have been working only four and, in certain cases, three days a week, sharing bonus losses with employees on a "50-50" basis.

Although material and component shortages have set a low ceiling to engineering output, certain other adverse factors have been in evidence during the past year. Labour turnover has been high, particularly in factories located in areas of industrial concentration where there has been competition for available labour. Employees have been free to change their jobs as they pleased and have taken full advantage of it. The chairman of a large concern manufacturing heavy motor vehicles, in the London area, said that, during the past three years, labour turnover had been so heavy that his company lost almost as many workers as it employed, the average turnover being in the region of 20 to 30 a week. This was in spite of the fact that earnings were higher than the average for the engineering industry. Many smaller firms, unable to offer the same opportunities for earning a high bonus, have been even more severely affected. In part, this tendency to change jobs has been due to the difficulty experienced by many ex-Service men in settling down to a routine, though there is some evidence that this influence is on the wane; but it is also symptomatic of the greater freedom that labour has enjoyed since a state of full employment has prevailed. Whether or not managements will be able to hold their labour, and to obtain good and willing service from employees who do not fear dismissal, has been the subject of much controversy since the end of the war. Little evidence has been produced by either side to support their views. Those who maintain that industry cannot be efficient unless there exists unemployment of some 3 to 6 per cent. of the working population, are faced with numerous examples of fully efficient works where production per man is high and discipline excellent. Others, who hold that the fear of unemployment is a discouragement, must acknowledge the good results obtained in pre-war days by some autocratic employers who refused to recognise the trade unions. It is significant, however, that most of the leading companies in the latter group have now adapted themselves to the new conditions prevailing in the labour markets, recognise the unions, and have elaborate machinery for joint consultation.

It is inevitable that, so long as the demand for labour exceeds the supply, there will be a situation in which organised labour is in an exceptionally strong bargaining position regarding hours, wages, working conditions and, not the least, the works "atmosphere." To recognise this and take appropriate measures to comply with the new conditions—to set up or revive Joint Production Committees, to improve working conditions and amenities, to establish cordial labour-management relations—is now the only course open to engineering firms if they are to retain their labour force (particularly their skilled labour), to recruit apprentices and to obtain good services from their employees. Productive efficiency must be based on security of employment rather than on the fear of unemployment, which will demand some considerable readjustment of outlook on the part of managements and men, and inevitably will be a slow and difficult process. Obviously, those who most quickly adapt themselves to the new conditions will benefit and the others will lag behind. The only alternative, however, appears to be the establishment of stringent labour controls on the war-time pattern.

The paramount importance of good management-labour relations is widely recognised by the Government, the trade unions and many employers. In April, 1947, the National Joint Advisory Council recommended the setting up of Joint Production Committees "where they do not already exist for the regular exchange of views between employers and workers on production questions," though insisting that "such machinery will be purely voluntary and advisory in character," and that "it will not deal with questions relating to terms and conditions of employment which are normally dealt with through the ordinary machinery of joint negotiations." This is a logical development of the policy, supported by Sir Stafford Cripps, of consulting both sides of industry on all production matters. War-time experience has shown the importance of giving employees frequent opportunities to exchange ideas with the management.

Another important development was the industrial Organisation Bill, which proposed the establishment of Development Councils for individual industries or groups of industries as a means of fostering joint consultation between management and labour; but, as in the case of Joint Production Committees, the authority to deal with wages and conditions of work is specifically excluded. Development Councils were recommended by most of the Working Parties to serve as a means of increasing co-operation between management and labour, for the collection of statistics, the establishment of design centres, the promotion of uniformity in accounting practice, and to serve as a link between the Government and the industry concerned. In the Parliamentary debate on the Bill, fears were expressed that the proposed Councils might overlap or interfere with existing trade organisations. The Government propose to issue the summary of the Order in Council establishing each Council, to allow a careful scrutiny of the terms of reference. Development Councils should provide at industry level what Joint Production Committees are intended to provide at workshop level and Advisory Councils at top levels.

Evidence that the trade unions are gradually changing their attitude to restrictive practices and incentives to work was provided by Mr. Jack Tanner at the annual conference of the Amalgamated Engineering Union, when he appealed to delegates to change their attitude to such matters as "time and motion study . . . which have nothing of Bedeaux about them." The trouble is that these methods have been associated for so long in the minds of employees with unemployment or increased profits for employers that the rank and file find it difficult to accept the idea that such methods could actually benefit them by ensuring the maximum return for effort and by eliminating rate cutting, which has been one of the root reasons for the opposition in the past.

There is also evidence that much of the unions' former hostility to piece-work and bonus payment has disappeared. In April, 1946, the Ministry of Labour carried out a survey of the proportion of time-workers and piece-workers in manufacturing industry. This proportion varies widely from industry to industry. Of the 5,750,000 persons covered by the survey, piece-workers accounted for 26 per cent., only 1 per cent. more than in October, 1938. In the metal, engineering and shipbuilding industries, about 46 per cent. of the men were working on piece rates, and in a few individual industries, including iron and steel manufacture, electrical engineering and motor-vehicle manufacture, the proportion was over 50 per cent., while, in the case of fitters, turners and other machine workers, it was about 75 per cent. There is scope, however, for the extension of piece-work operation in the engineering industry and this was being considered towards the end of last year. An agreement has been reached to cover the payment of patternmakers, and negotiations for its introduction into foundries are proceeding. Most of the large engineering works already operate systems of payment by results and it is, in the main, small firms who adhere to the time basis. These might well benefit from the introduction of the piece-rate system, although it is unlikely that it will be widely adopted until supplies of materials and components allow full employment of available labour.

During the debate on productivity, in the House of Commons in April, 1947, the need for improving management methods was emphasised. Few questioned that there was some slackness on the part of labour, but this was most widely interpreted as the failure of management in the sphere of labour relations and applied incentives. Certain managements have secured remarkable success in their production drive, and often by most unorthodox methods. For example, when Mr. C. B. Colston, chairman of Hoover, Limited, of Perivale, spoke to his employees after the fuel crisis and asked them to work harder to make up output losses, these losses were made up and exceeded in two months. In return for this effort, Mr. Colston gave a party at the works, with a firework display, circus show, bands, dancing, food and soft drinks, the whole being provided at the company's expense, except for the beer and spirits. There are few examples of this kind, but there is no doubt that, when labour-management relations are good, improved effort is readily obtained.

The introduction of the five-day week at the end of 1946 was opposed by many on the ground that production would fall at a time when everything depended on increased output. The shortage of materials and components invalidates most calculations made on the basis of output over a given period, but there is ample evidence that attendances and individual effort have improved in many cases. Much depends, however, on local circumstances. The survey conducted by the Philips (Electrical Manufacturing) Group of companies, among firms which had introduced the five-day week in the engineering, printing, textile, and boot and shoe industries, showed that, in many cases, production had benefited as a result of better time-keeping and attendance, and that it was in no case affected adversely by the new schemes. Several other engineering companies report good results, though the majority state that a loss of production was recorded initially. Others have had more difficulty in making up this initial fall in output. The heavy-motor firm mentioned earlier in this article experienced an initial drop of 6 per cent. in output following the introduction of the 44-hour week. Gains obtained from more regular attendance and harder work averaged 3 to 3½ per cent., but the chairman doubted whether the rest could be made up. He complained that there appeared to be a deep-rooted prejudice against earning too high a bonus, though he could not point to any cause. This is evidence that much remains to be done to overcome the many prejudices which still affect the attitude of employees to all-out production. Many restrictive practices were given up during the war, but it is likely that, as soon as labour begins to be declared redundant—for example, in those factories which are unable to export their goods—they will once more return to pre-war habits. Mr. George Isaacs, the Minister of Labour, stated, in July, 1947, that neither of the two parties concerned had come to him with any proposal for the restoration of these pre-war restrictive practices, and that, therefore, the best thing to do was "to let sleeping dogs lie." While this may be the correct Government policy, it would be a negative attitude for management to adopt, and would most certainly lead to renewed labour unrest.

In February, 1947, the Court of Enquiry appointed to investigate the claim of shipbuilding workers for a 44-hour five-day week published their report. Taking as their starting point the long-established connection between shipbuilding and engineering, where the principle of the five-day week had been

established already, the Court recommended for shipbuilding a 44-hour five-day week from March to October, and a 44-hour week of 5½ days from November to February. This 5½-day week during the winter recognises the industry's need for daylight working, especially on the ship-repairing side, where harbour dues still have to be paid for idle week-ends. The recommendations apply only to hours, however, and their effect on wages and production has still to be negotiated and worked out. The fact that no agreement had been announced by the end of the year is ample proof of the delicate and difficult nature of the negotiations.

In sharp contrast to the aspirations of shipbuilding employees for shorter hours, in the steel industry an agreement was made between the Iron and Steel Trades Employers' Association and the Iron and Steel Trades Confederation as from April 6, 1947, to operate smelting furnaces in the heavy steel industry throughout the week-end on the basis of a 48-hour week. Agreement has also been reached to work week-end shifts on furnaces which cannot yet operate fully throughout the week. Hitherto, steel furnaces have been damped down between Saturday and 2 p.m. on Sunday. Continuous seven-day working should make it possible to produce an additional three-quarters of a million tons a year from those furnaces at present able to work a seven-day week. When all plant is able to operate on the new basis, the output of steel ingots should be increased by a million tons a year.

In July, 1947, the report of the Committee appointed by Mr. Ernest Bevin in March, 1945, "to enquire into the economic need for and the social consequences of the double-day shift system in manufacturing industry," was issued (Cmd. 7147). The Committee were mainly concerned with the long-term aspects of shift work, but the report was published at a time when manufacturing concerns were endeavouring to introduce double-shift systems in their efforts to stagger working hours in order to avoid electricity cuts. Shift work, of course, is accepted as inevitable in a number of heavy industries such as mining, railways and foundries, but it has been regarded hitherto as an emergency measure in manufacturing industry. The unions have opposed two-shift working on social rather than economic grounds and the acceptance by the Trades Union Congress of the principal findings of the Committee—provided that satisfactory wages and conditions are negotiated—revealed a major change in outlook.

The Committee found that the system of double-day shift work "is undoubtedly capable of making an important contribution to the economic well-being of the country." The Committee agree that it has an important effect on the development and re-equipment of industry, and seem to have been particularly impressed by the findings of the Cotton Spinners and Manufacturers' Association, "that it is essential for automatic looms to run at least two shifts to make them an economic proposition." This applies to most of the manufacturing industries equipped with a high proportion of automatic special-purpose machinery, and should reduce costs considerably in industries such as the motor-vehicle manufacturing industry, the light electrical-engineering industry, and all others operating bulk or mass-production methods. While the Committee recognised the very real social difficulties of re-organising working hours and the possible dislocation of family life, they found certain compensating factors; for example, they did not find any evidence to support the view that two-shift systems were detrimental to health, and the conclusion was reached that there should be compensating benefits in shorter hours and a long week-end. The Government have accepted the broad lines of the Committee's report, but have considered it unnecessary to retain the full legal requirements which at present govern the adoption of double-shift working, provided that adequate powers are maintained to protect the health and welfare of shift workers.

About a month after the publication of the Committee's report on double-shift working, it was announced that full agreement had been reached between engineering employers and trade unions on the terms and conditions for staggered hours to reduce the electricity load. This agreement was reached after months of negotiation and both sides have had to make concessions. The unions have agreed to give up their five-day week and to work on Saturday morning at normal rates, where this is necessary to make up a full working week of 44 hours. The employers, on their side, have agreed to pay night rates for night shifts in spite of the increase in costs which any considerable transfer to night working must entail. Both sides have agreed to compromise on the question of overtime rates for abnormal day-time hours. A memorandum accompanying the agreement emphasised the need for local flexibility, and pointed out that detailed arrangements for shedding the load must be determined in each region in the light of local availability of power. It also stressed that the arrangements should be regarded as temporary in character and should not represent a permanent system of working.

What are the manpower prospects for engineering in 1948? The answer must be found from an investigation of the general labour situation, and an examination of the main trends that have become apparent during 1947. The distribution of total manpower in Great Britain, given in Table I, herewith, and taken from the *Monthly Digest of Statistics*, shows that the total working population, including the armed Forces, has tended to decline slightly over the past year. In September, 1947, the total working population was 1,900,000 below the level of June, 1943, having declined by 159,000 since June, 1946. The labour available in manufacturing and non-manufacturing industry, however, in September, 1947, was 1,300,000 greater than in June, 1946, and 556,000 greater than in June, 1939. Unemployment, which had risen to 2,300,000 during the fuel crisis in February, was remarkably low in September, when it stood at 250,000, or 1·2 per cent. of the total working population. It is most unlikely that this figure can be reduced very much farther; on the contrary, temporary unemployment is likely to increase over the next few months if the Government's threat to curtail material supplies to firms unable to export their goods is carried out.

It would appear, therefore, that any further increase in the manpower available for industry must come, in the main, from further reductions in the armed Forces and from the recruitment of women. In September, 1947, the number of women employed was more than 1,500,000 below the peak level reached in 1943, and scope should exist, therefore, for further recruitment. In June, 1947, the Government launched a campaign, opened by the Minister of Labour in a broadcast to the nation, calling for 300,000 recruits. The Government have not been helped in their campaign by their refusal to accept the general principle of equal pay. The Chancellor of the Exchequer explained that the country, already committed to a heavy programme of social services, was ill-equipped to bear further non-productive expenditure. There is no doubt that the trade unions will bring additional pressure to bear on the Government at forthcoming conferences, and will put forward the shortage of woman

TABLE I.—DISTRIBUTION OF TOTAL MANPOWER, 1939 TO 1947. (THOUSANDS.)

	1939, June.	1943, June.	1946, June.	1947.		
				June.	August.	September.
Total working population	19,750	22,281	20,523	20,357	20,343	20,364
Males	14,656	15,028	14,638	14,618	14,624	14,625
Females	5,094	7,253	5,885	5,739	5,719	5,739
Armed Forces and auxiliary services	480	4,757	2,032	1,292	1,242	1,232
Civil Defence, National Fire Service and Police	80	323	88	91	91	91
Industry	17,920	17,121	17,327	18,559	18,633	18,676
Ex-members of H.M. Forces who have not yet taken up employment	—	20	700	155	135	115
Insured persons registered as unemployed	1,270	60	376	260	242	250

TABLE II.—ESTIMATED NUMBERS EMPLOYED IN METAL-WORKING INDUSTRIES,* 1929 TO 1946; METAL MANUFACTURE, METAL GOODS, ENGINEERING, VEHICLE, AIRCRAFT AND SHIPBUILDING INDUSTRIES (THOUSANDS).

	Total.	Males.	Females.	Employed on Orders for		
				Supply Depts.†	Home Market.	Export.
1929, July	1,905	1,635	273	—	—	—
1939, June	2,716·7	2,289·6	427·1	—	—	—
1943, June	4,586·4	2,959·0	1,627·4	3,844·1	673·0	69·3
1946, June	3,205·5	2,416·7	788·8	433·0	1,992·5	780·0
1947, June	3,392·6	2,656·1	736·5	2,482·7		909·9
August	3,396·1	2,663·2	732·9	2,454·3		941·8
September	3,409·9	2,672·2	737·7	2,389·7		1,020·2

* Great Britain, males aged 14 to 64 and females aged 14 to 59; but excluding non-manual workers earning over 420*l.* pe rannum. Part-time female workers are included, two being counted as one unit.
† Mainly equipment and stores for armed Forces.

TABLE III.—ESTIMATED NUMBERS EMPLOYED IN THE METAL MANUFACTURE, METAL GOODS, ENGINEERING, VEHICLE, AIRCRAFT AND SHIPBUILDING INDUSTRIES, 1939 TO 1947 (THOUSANDS).

Industries.	1939, June.	1943, June.	1946, June.	1947.			September, 1946. Labour Force as Percentage of 1939 Figures.
				June.	August.	Sept.	
Pig iron (blast furnaces) steel smelting and iron puddling, iron and steel rolling, etc.	175·5	212·8	187·5	193·1	194·6	195·9	112
Manufacture of non-ferrous metals	55·9	114·4	79·8	87·6	87·7	88·2	158
Manufacture of tinplate	25·1	13·8	12·1	15·0	14·8	14·7	59
Iron and steel tube, wire, wire netting and wire rope manufacture	58·5	77·3	62·9	62·8	62·3	62·5	107
General engineering, engineers' iron and steel founding, etc.	704·7	1,459·8	902·4	948·1	955·8	961·7	136
Marine engineering	52·2	88·9	72·0	68·1	67·3	67·0	128
Electrical engineering	133·9	193·3	153·1	154·3	154·4	155·1	116
Constructional engineering	49·0	48·9	55·5	66·2	65·0	64·9	132
Motor vehicles, cycles and aircraft	473·3	1,121·8	552·4	560·6	558·6	557·7	118
Shipbuilding and ship repairing	144·7	272·3	229·1	214·7	214·0	213·3	147
Construction and repair of railway and other carriages and wagons, etc.	65·6	59·1	73·7	86·5	87·5	88·2	135
Bolts, nuts, screws, hand-tools, brass and allied metal ware and miscellaneous metal goods	378·1	447·8	401·8	457·4	455·2	457·2	121
Electric cables, apparatus, etc.	195·9	291·0	244·2	276·2	278·0	281·4	143
Scientific instruments	48·2	81·2	63·1	67·4	67·6	68·0	141
Watches, clocks, plate, jewellery, etc.	38·7	18·2	24·4	31·6	31·4	31·4	81
General ironfounding, heating and ventilating apparatus	117·3	85·8	90·5	103·0	101·9	102·7	88
Totals: Males	2,289·6	2,959·0	2,415·7	2,656·1	2,663·2	2,672·2	116
Females	417·1	1,627·4	788·8	736·5	732·9	737·7	173
Grand Total	2,716·7	4,586·4	3,204·5	3,392·6	3,396·1	3,409·9	126

labour in industry as a strong argument in favour of equal pay.

Table II, opposite, abstracted from the same issue (November, 1947) of the *Monthly Digest of Statistics*, shows the estimated numbers employed in the metal and engineering industries. The figures show a most satisfactory increase over the past year, an increase of over 200,000 having been registered from June, 1946, to September, 1947. This increase consists entirely of men, the number of women having declined by about 51,000 over the same period. This fall in the female labour employed appears to have been checked in mid-1947, and the September figure shows an increase of some 5,000 over the previous month.

The rise in the labour force in the metal and engineering industries has not been evenly distributed over all sections; this is shown in Table III, opposite, and, like the previous tables, is compiled from the *Monthly Digest of Statistics*. Some sections, such as tinplate, watches and clocks, and general ironfounding have been unable to regain their pre-war labour strength. Other sections, producing less than pre-war because of material shortages, employ more people; an example of this is the motor-vehicle, cycle and aircraft group of industries. Space prevents a detailed analysis of the maldistribution of labour in the metal and engineering industries, but the position in individual industries will be examined in subsequent articles. The problems of the tinplate and ironfounding industries are probably the most acute and pressing; in the South Wales tinplate mills, a short week of 36 hours is worked, mainly with the object of attracting new labour to old-type mills. Figures given by the British Iron and Steel Federation for employment in iron foundries show that, from September, 1946, to September, 1947, the labour employed increased by 12,600, which is quite inadequate if the full demand for castings is to be met. The labour situation is likely to continue to be difficult during the current year. Apart from the obvious maldistribution of available labour supplies between individual industries and within each industry, the future availability of juvenile labour is giving cause for some justified alarm. The present general shortage of juvenile labour results from a fall in the birth rate 10 to 20 years ago, from the withdrawal of large numbers of boys and girls between the ages of 14 and 20 from the labour market through the raising of the school-leaving age, and from the decision to continue compulsory military service.

Immediately before the war, there were 5,500,000 young people between the ages of 14 and 20, of whom some half a million were at secondary schools, technical colleges, universities and other institutions giving full-time education, thus leaving a balance potentially available for work of almost 5,000,000. By the end of this year, the very severe fall in the birth rate in the early 1930's will have reduced the total number of children between 14 and 18 by over a million: to this natural fall must be added the young men on military service, and the boys and girls between 14 and 15 who will be staying on at school because of the raising of the school-leaving age. The effect of all these changes will be to reduce the number of children available for employment from just under 5,000,000 to just over 3,000,000—a very severe drop for a single decade. There will be a further reduction in the number of young people in the labour market between 1948 and 1958, although, owing to a rise in the birth rate between 1940 and 1944, there will actually be slightly more children aged between 14 and 20 in 1958 than there will be at the end of this year. By that time, however, the school-leaving age will probably have been raised to 16, and part-time education will have become compulsory for one day a week for all those between 16 and 18. The balance available for employment will therefore have fallen to just over 2,000,000 as compared with 5,000,000 in 1938.

Engineering employers will have to act quickly to meet this threat and, so far as possible, must see that machinery is available to carry out many operations formerly performed by juveniles. Considerable economies will doubtless be effected, as the cost of juvenile labour rises. In the London area, the seriousness of the situation is shown by a Report of the London Regional Advisory Council for Juvenile Employment for the years 1939-46. Between these two years, the juvenile labour available in London declined by 30 per cent., from 408,000 to 287,000. Just before the war, the total number of unfilled vacancies was 8,000, or approximately 2 per cent. of the total juvenile labour force. By the end of 1946, this number had risen to 42,000, or 15 per cent. of the total of juvenile labour. Figures published in the *Ministry of Labour Gazette*, November, 1947, showing the recruitment of juvenile labour by individual industries, are given in Table IV, herewith, for selected industries. The trends are clear—coal, textiles and clothing, distributive trades, agriculture, and the metal industries are recruiting considerably less than pre-war. Engineering, vehicles and aircraft, shipbuilding, and the building trades are recruiting substantially more; for example, the latter group of industries accounted for 17·9 per cent. in 1946-47, compared with 11·2 per cent. in 1937-38. This table summarises the man-power problems that the Government have to face. The first is of general shortage—528,000 juveniles in 1946-47, compared with 668,000 in 1937-38. The second is one of maldistribution. The undermanned industries—coal mining, agriculture, iron and steel foundries, tinplate, textiles and clothing—are failing to obtain sufficient numbers of new entrants to increase, and even, in some cases, to maintain, their labour strength.

TABLE IV.—*Recruitment of Juvenile Labour.*

Industry.	Boys aged 14 to 17.		Girls aged 14 to 17.	
	1937-8.	1946-7.	1937-8.	1946-7.
Engineering	27,989	29,632	6,851	7,919
Vehicles and aircraft ..	14,:09	20,152	2,785	3,514
Shipbuilding	3,049	4,071	200	250
Elec rical apparatus, cables, lamps, etc. ..	5,627	4,387	4,455	3,618
Building and civil engineering	18,159	27,150	1,559	1,628
National Government service	4,621	5,654	3,088	7,271
Local Government service	4,014	4,389	2,215	7,748
Agriculture, horticulture, etc.	19,259	16,594	3,779	3,116
Coal mining	15,154	6,438	488	339
Metal and metal goods manufacture ..	21,847	18,469	13,624	10,217
Textile and clothing industries ..	17,181	9,818	64,679	52,692
Distributive trades ..	108,699	41,061	86,614	71,520
Total	358,852	267,403	308,776	260,196

The first problem can be solved by cutting the size of the armed Forces and successfully recruiting women, by finding jobs for persons not formerly employed, and by importing foreign labour. In spite of the withdrawal of opposition in some cases, there is still strong resistance in many industries to this recruitment of foreign labour. An example of the unions' attitude is provided by the categorical refusal on the part of the Amalgamated Engineering Union to allow the employment of Poles in engineering. The T.U.C., as a whole, have agreed to the employment of Poles, subject to certain conditions, one of which is that the individual local trade union should be consulted. In the case, of the A.E.U., the opposition is partly based on the fear that Polish labour will deprive British workpeople of their jobs, since engineering is not an undermanned industry; this is in spite of the Government's assurance that Poles will only be used where there is a shortage of British labour, and will be discharged first should there be unemployment. The political hostility, both among the rank and file and the shop stewards, and among the A.E.U. leaders, is strong.

The second problem, that of maldistribution, is much more difficult to solve. A possible solution lies in offering would-be recruits inducements to enter undermanned industries. This, in fact, means a wages policy, since raising wages in coal mining, in agriculture, and in transport will inevitably start demands for wage increases in other industries. Any suggestion that such a policy might be adopted has been strongly resisted hitherto by the trade unions, which jealously guard their autonomy in this matter. The Government were sharply informed at the Labour Party Conference at Margate that wages were a matter for negotiation between the two sides of industry. The Government's anxiety to arrest the upward movement of wages was reflected in the Minister of Labour's decision to circularise Joint Industrial Councils in September, 1947, calling their attention to the Prime Minister's appeal to unions not to press for wage increases at the present time. The letter had a poor reception from the Trades Union Congress, which immediately feared Governmental intervention and requested a meeting with the Prime Minister, at which Mr. Attlee reaffirmed the Government's intention to leave wage questions to be negotiated between the two sides of industry. In an interim statement on economic policy, published at the end of December, after two months of discussion between its representatives and members of the Government, the General Council of the T.U.C. declared that wages must be negotiated freely by the two sides of industry, that subsidies must be continued, that prices must be kept stable, and that output must be increased.

The statement ignores entirely both the dangerous and distorting degree of inflation that already exists and the serious maldistribution of labour and resources that is the consequence. There is evidence, however, that such a view is not unanimously held by T.U.C. officials; for example, Mr. Jack Tanner, President of the A.E.U., stated at the annual conference of his union, held in mid-June, that "There is a danger that a square deal for these [undermanned] industries may provoke less justified claims by workers in other industries . . . It is essential that trade unions maintain a statesmanlike policy of tolerance and restraint." This would seem to imply that the union leaders in the better-paid industries, such as the engineering industry, are prepared to discourage their members from pressing for wage increases; but it is doubtful how far the former would be able to withstand pressure for higher wages from their rank and file in the face of any large wage increases in undermanned industries such as mining and textiles. The Court of Enquiry set up to investigate a claim by the National Union of Railwaymen for an additional 1*l.* per week recommended an increase of 7*s.* 6*d.* The Court stated: "We are aware of the tendency for wage increases in one important industry to have repercussions on the wage structure throughout the country, and we wish to make it clear that our recommendations have had regard to the special circumstances of the railway industry at the present time and are not intended to serve as a basis for a general upward movement of wages as a whole." Notwithstanding this and other similar statements, in October the Ministry of Labour reported an increase of over 800*l.* million in the weekly full-time wages of 2,600,000 persons and substantial reductions in hours affecting some 4,500,000. It is known that, towards the close of the year, discussions on wages policy were proceeding behind closed doors at Transport House. Among the tentative proposals put forward by the Government was one for a "points" scheme for wages, under which the undermanned industries would rate high for increases, while industries already fully manned or in "non-essential" categories would not qualify. In the event of the unions refusing to accept some such policy, the only alternative open to the Government for securing a better distribution of available manpower will be through controls and direction.

Although the T.U.C. at Southport accepted the necessity for some form of direction of labour, this was done reluctantly. The delegates wanted to be assured that direction would be applied fairly to every section of the community and not merely against weekly wage-earners, and that there would be adequate safeguards in its operation. The Government therefore introduced the Control of Engagements Order, which became operative on October 1. Apparently, it follows closely on the lines of its war-time precedent, the Essential Works Order, which still covers coal mining, agriculture, building and civil engineering. The Government have repeatedly promised that the powers of compulsory direction would be used as a last resort and that they would proceed by persuasion as far as possible. The Minister of Labour stated that the Order would provide Employment Exchanges with some 400,000 cases to handle each week, instead of the normal 200,000. He attached much more

importance to guidance provided by the Exchanges —offering essential work to appropriate persons and indicating to them where their duty properly lay —than to the ultimate threat of compulsion. A list of essential industries was circulated to Employment Exchange managers, on which full priority was given to mining, agriculture, iron and steel and textiles. Engineering, while essential for exports and re-equipment, was not considered to be seriously affected by labour shortages except in certain cases and, therefore, was omitted from the list. Sections of certain industries, where there is no general shortage of labour, are also classified as essential; for example, the manufacture of refractory bricks, and some sections of heavy engineering, such as the production and repair of electrical generating plant, railway locomotives and coal wagons, and mining machinery.

The lists are not final, and no hard and fast definition of "essentiality" has been laid down. The main decisions on priorities must rest with the local and regional authorities; the Ministry of Labour has been mainly content to define broad categories and to emphasise the need for flexibility. The first results of the Order have been encouraging. In all, "first preference" industries gained 15,700 employees in October, compared with an average monthly increase of 3,900 in the previous three months. Some increases are very striking. Cotton spinning, in which the labour force had been increasing by about 300 a month, gained 2,400 in October, while cotton manufacturing, which had been losing 300 a month, gained 13,000. Recruitment in the wool textile industry rose from 800 to 3,100, and ironfounding, which had been losing men recently at the rate of 200 a month, gained 1,600. It is to be hoped that the initial success will be maintained. It is possible that the Order will limit the turnover of labour, since employees may prefer to remain in their jobs rather than risk being sent to work they do not like, under the threat of compulsory direction. If the scheme is not successful, redeployment of labour is likely to become a very slow process, dependent on a gradual reduction in the employing capacity of the overmanned and non-essential industries through limitations on fuel and raw material supplies.

FLOATING COMPRESSED-AIR PLANT.

EASE of access to a ship lying afloat at a quay can have a material effect upon operating and maintenance costs, and, therefore, any development that reduces the amount of equipment and incidental gear on the quay is worth consideration on that account. An innovation of this kind that appears to offer useful possibilities is a floating air-compressor plant recently put into service at Amsterdam by Messrs. J. C. van Alphen en Zonen, who are contractors for scaling, cleaning, painting and similar "servicing" of ships. To enable such work to be carried on from the offside of ships lying alongside quays, or moored away from the shore, the firm decided to mount their air compressing equipment on a barge; but, to make the plant also available elsewhere, they selected compressors of the portable type, carried on a pneumatic-tyred four-wheeled chassis.

The compressed-air plant, with a full equipment of chipping and scaling hammers, air-operated wire brushes, and water pumps, also driven by air motors, was supplied by Messrs. Broom and Wade, Limited, High Wycombe, through their Dutch agents, Messrs. van Rietschoten en Houwens, of Rotterdam. The two portable sleeve-valve compressors are of different sizes, the smaller being of the makers' SVD.2 type, and the larger, the SVD.3 model. The former, which is driven by a Lister 38/4 hand-starting Diesel engine, developing 40 brake horse-power at 1,000 r.p.m., delivers 167 cub. ft. of free air per minute at a pressure of 100 lb. per square inch. The latter is driven by a Gardner 6LW Diesel engine of 60 h.p., running at 1,100 r.p.m., and has a capacity of 250 cub. ft. of free air per minute at the same pressure. In each case, the engine is coupled directly to the compressor through an automatic centrifugal clutch. The barge is 20 m. in length, and, to house the compressors, was fitted with a superstructure over the hold, with removable hatch covers to permit either or both of the sets to be dismounted readily for use on shore. An air delivery pipe and control valves are provided in the superstructure, and, as the sets normally work in the comparatively small enclosed hold, connections were provided to the engine and compressor cooling systems to enable a continuous circulation of cooling water to be maintained.

LABOUR NOTES.

IN terms which were frank and obviously directed at the General Council of the Trades Union Congress, Sir Stafford Cripps dealt with the general wage question on Wednesday last week. He said: "Hitherto we have been inclined to suppose that production was all that mattered, irrespective of costs. This has encouraged a general rise in prices and wages which can only lead to uncontrolled inflation, and will ruin our trade. We must set about reducing costs as vigorously as we can. While maintaining wages, we must economise in our production costs by better methods. Improvement of design can ensure that less effort produces the same results. The detailed planning of production can reduce delays, and so costs. Costs can also be lowered through an improvement in the relation between workers and managers—through a willingness on both sides to hold back nothing which can contribute to the national welfare. Every unjustified increase in export costs tends to reduce the workers' rations."

Continuing, Sir Stafford said: "While the index of retail prices has remained pretty stable over the past year, weekly wage-rates have shown a steady increase. At the beginning of 1947, they were 65 per cent. above pre-war—a figure which by November had reached 73 per cent. During the 11 months, 4,632,000 workers received increased wages, the estimated net weekly increase being 1,637,200*l*. These increases were not confined to under-manned industries, to which it is necessary to attract workers. Their widespread nature was a source of concern amid the increasingly competitive conditions in which we are selling our manufactures abroad. Their only justification in our present circumstances was if they yielded better results in the general productivity of our industries."

"Efficiency of production," Sir Stafford added, "is still a cardinal need. There is a great deal that can be done by agreement between management and workers, by getting rid of all hindrances to production, by using new methods, and by a redeployment of labour. We are nowhere near the maximum production that can be got from our existing machinery, quite apart from the improvement that we are daily making in our industrial equipment."

The mineworkers of Great Britain just "failed" to reach the Government's "target" of 200,000,000 tons in the 53-week "year" that ended on January 3. According to provisional figures compiled by the Ministry of Fuel and Power, the total output in the 53 weeks was about 199,700,000 tons. Commenting on the figures, Mr. Hugh Gaitskell, the Minister of Fuel and Power, said that there would be, of course, some disappointment that the 200 million target had not been reached, but 99·8 per cent. was very near to it. Anything like that total seemed out of range only a few months ago. It had been a great finish, and he congratulated everyone concerned.

Lord Hyndley, chairman of the National Coal Board, said that although his colleagues and himself would have liked to see the miners hit the target, they were nevertheless delighted with the result achieved, and sent to all in the coalfields warmest congratulations. "This year," he added, "a further, and even greater, increase in production is essential. Let us get down to it at once."

The Ministry of Fuel and Power states that in the Christmas holiday week, the increase in absenteeism in the mines was considerable, although the figures were a great improvement compared with 1946. In the week ended December 20, 1947, the percentage of voluntary absenteeism among coal-face miners was 5·74. In the week ended December 27, it was 11·19. In the week ended December 28, 1946, it was 19·91. The percentage of involuntary absenteeism among coal-face miners was 4·88 in the first of the two weeks, and 5·12 in the second week. The corresponding figure for the week ended December 28, 1946, was 8·30.

Leading representatives of two of the unions of railwaymen circulated "Nationalisation Day" messages to members. Mr. J. B. Figgins, acting general secretary of the National Union of Railwaymen, expressed confidence that under the new regime the transport system would be operated in a highly efficient manner to the great benefit of the general public and also to that of British industry as a whole. The fullest co-operation would be forthcoming, he said, from the whole of the staff. "I am satisfied," he added, "that the new organisation will make the British transport system an example to the rest of the world. Mr. J. G. Baty, acting general secretary of the Associated Society of Locomotive Engineers and Firemen, said in his message: "We intend fully to collaborate with the object of making British railways 100 per cent. efficient."

It is assumed by the railwaymen's trade unions that the various labour questions raised by them have been taken over by the new Railway Executive, and that joint consideration of them will shortly begin. Of these outstanding questions, the most important are, of course, the proposals for a new wage structure for the conciliation grades put forward by the National Union of Railwaymen and the Associated Society of Locomotive Engineers and Firemen at their conference with the railway companies on December 9. New wage claims by railway shopmen and salaried staffs, including members of the Railway Clerks' Association, are, however, considered to be likely, and so are applications for increases on behalf of persons employed on what were the London Passenger Transport Board's road services. The passenger section of the Transport and General Workers' Union has prepared a detailed claim to be submitted soon to the new London Transport Executive which has taken the place of the London Passenger Transport Board.

The National Coal Board has officially denied a statement which received some publicity recently to the effect that of the rise of 6*s.* 6*d.* per ton in the pithead price of coal in 1947, 1*s.* 8*d.* had "gone to pay for unproductive officials compared with 2½*d.* per ton under private enterprise." "In 1946," the Board states, "before nationalisation, the cost of clerical, technical, and managerial staff was about 1*s.* 2*d.* per ton. Now, it is about one penny more (and not 1*s.* 8*d.* more as stated) despite the many services, such as medical, training, scientific, and educational, which are being extended to the industry as a whole."

In the course of some notes on the operation of its Personnel Management Branch, the Ministry of Labour and National Service cites, in *Information Service*, two instances which it thinks, serve to show the value of good personnel management in improving morale and production, even in units which are not troubled by the difficulties attendant upon large-scale organisation. A firm of soap manufacturers employing about 150 persons—about half of them women—was seriously concerned about a high rate of absenteeism and labour turnover.

They discussed the matter with the Ministry's Personnel Management Advisers, and the conclusion was reached that the position would be helped if a committee were set up consisting of representatives of the management and the employees. This was done carefully and without haste, and, at the same time, one of the management was made responsible for certain aspects of the personnel work which had not previously been covered satisfactorily. At the end of six months, the firm informed the Adviser that they thought they had solved most of their major personnel problems.

Another firm, with rather more employees, engaged in the hosiery industry, was convinced of the importance of good personnel management. Their production figures, the Ministry state, were, on the whole, satisfactory, but they thought that improvement was still possible. One of the staff was appointed Personnel Supervisor and sent for special training, a Works' Committee was set up, and better methods were instituted for the selection, introduction, and training of new employees. "The result, very quickly seen, was an increase of output per head of almost 10 per cent."

The Ministry add that Personnel Management Advisers are available to visit any firm which would like to discuss personnel problems with them or which are considering a development of their personnel organisation. The Advisers are posted in the various Factory Inspectorate Divisions with offices in London, Manchester, Liverpool, Birmingham, Newcastle, Glasgow, Leeds, Wolverhampton and Bristol, and firms desiring to get in touch with the Adviser for their area may do so through the Superintending or District Inspector of Factories.

Non-unionist building trades labourers employed by Coventry Corporation are in future to be paid at the rate of 2*s.* 2½*d.* an hour, compared with 2*s.* 6*d.* an hour paid to trade unionists. This is the effect of a decision of the Corporation, by 30 votes to 15, to apply a 3½*d.* an hour increase over the national rate conceded by the Council in October last only to labourers who are trade unionists. Labourers who refuse to join the union—which is a unit of the National Federation of Building Trades Operatives—will receive a week's notice, and be offered re-engagement at the national rate.

WAR-TIME SHIP REPAIRS.

Fig. 5.

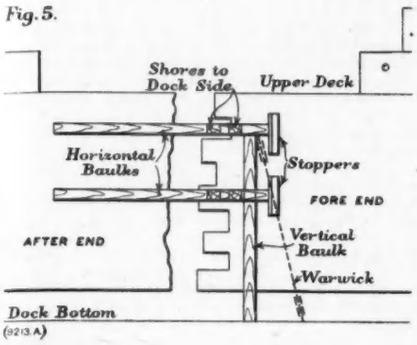
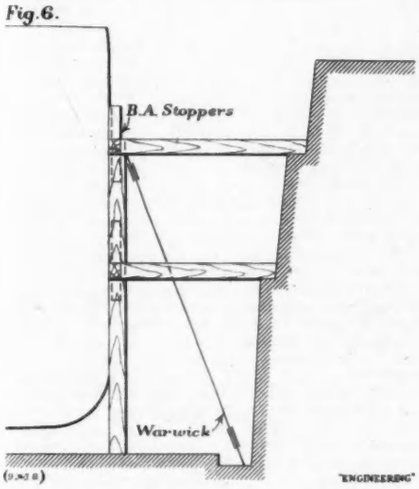


Fig. 6.



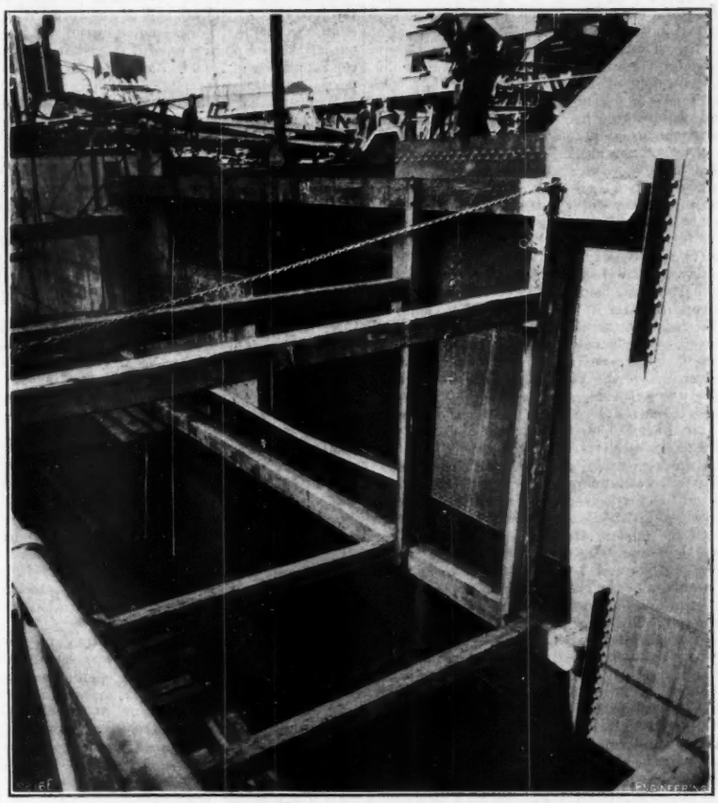


FIG. 7. ARRANGEMENT OF SHORING FOR M.V. "PONTFIELD."

SOME WAR-TIME SHIP REPAIRS.*

By E. J. HUNTER.

THE object of this paper is, primarily, to give an account of five major ship repairs carried out by the dry docks department of the firm with which the author is associated; all of them similar in character and method of execution, but each one in its way different and presenting its own individual problems. The type of operation described is no new thing to the ship-repairing industry; the same firm carried out repairs of this nature as long ago as 1905, namely, in the case of the Milwaukee and many similar repairs have been done from time to time by ship-repairers in this country.

The grafting of new forward halves on to the motor tankers Pontfield and Vardefjell, and the cargo ship Harpagus (now Treworlas), and the joining of the fore and after ends of the tanker Thorshovdi (now Giert Torgersen), are described in some detail; but the essence of the problem, in each case, was to locate the two portions of the ship, in dry dock, at the correct distance apart and in their proper relation in the horizontal and vertical planes. The case of the Standella was more in the nature of a surgical operation though the principles and method employed were basically the same.

At 2 a.m. on September 15, 1941, the Pontfield, a tanker of 8,319 gross tons, with engines aft, was proceeding in convoy, fully laden, in the North Sea, when she was subjected to an explosion from an acoustic mine. The result was that she broke in two at the pump room. The forward half sank, but the after half, which contained the engines, remained afloat and was towed into port. After discharging, the half vessel was brought to the Tyne with the assistance of tugs and was docked for examination on October 22, 1941. It was decided to reconstruct the fore end of the vessel and, to avoid occupying a large dry dock for many months, to build it complete in the normal way, launch it, and subsequently join the two halves together in dry dock. Templates were taken of the midship form of the ship in way of the break; the after end was undocked on October 31, 1941, and placed at buoys; and the building of the new fore end was begun immediately at Messrs. Swan, Hunter, and Wigham Richardson's Neptune yard. To cut down the time for joining-up in dry dock to a minimum, the building of the fore end was arranged so that, apart from frames, girders, etc., only one strake of plating on shell, deck, centre keelson and fore and aft bulkheads was necessary to complete the joining of the two halves.

The after end was redocked stern first on March 3, 1942, and the work of cutting away the damaged structure in way of the break and preparing for the docking of the new fore end commenced. The question then arose of how best to place the fore end in dry dock in its proper relation to the after end in the vertical and horizontal planes, and at the correct distance from it. The method adopted was to keep the after end on the dock blocks, and, after making all preparations to receive the fore end, to flood the dock and float the forward end into position.

To locate the fore end in dock at the correct distance from the after end, two 12 in. by 12 in. baulks were bolted through the frames to the sheer strake and the outside strake below on the starboard side of the after end, the ends of which were to engage with angles welded on to the corresponding strakes of the shell on the fore end. To ensure the two ends being at the right distance apart, one baulk would have been sufficient, but, as the after end as docked had a slight list, two baulks were used so that, by pulling the fore end firmly up against both baulks, as it settled on the blocks, it would assume the same degree of list as the after end. Before docking, it had been given the necessary degree of list by means of weights placed on the deck at the ship's side, and, as an additional visual check, a board with a plumb line against a line on the board was attached to the sheer strake. The arrangement of these baulks, which were securely shored from the dock bottom and the dock side, is shown in Figs. 5 and 6, and by the photograph reproduced in Fig. 7.

To reduce friction while the fore end was being lowered into position, the ends of the baulks were rounded and curved steel plates fixed to them, as shown in Fig. 7. To ensure the correct alignment of the two halves in the vertical plane, vertical sights were erected on the dock blocks and a line struck through from the after to the forward perpendicular of the ship; to the point on the blocks so obtained, a plumb line was dropped from a level batten at right angles to, and against, the dock altar. The point where the plumb line hung from the batten gave the correct position of the stem of the ship in the upright position but, as the after end had a slight known list, it was necessary to correct the point accordingly. With this batten prepared and the 12 in. by 12 in. baulks in position, everything was ready to bring the fore end into dock.

The Tyne being tidal, it is not easy to carry out docking operations except at high or low tide. Calculations showed that the draught of the fore end when launched would be too great for it to be docked with the amount of water available at low tide, whereas the amount of water over the blocks at high tide would cause the after end to float. It was decided, therefore, to flood the main cargo tanks of the after half with sufficient water to prevent it floating. As the amount of water was considerable, this had unfortunate consequences which, happily, it was possible to surmount.

The fore end was launched on April 30, 1942, and tied up alongside the yard, as, in addition to placing the weights on the deckside to give the required list, it was necessary to trim it by the head by an amount corresponding as nearly as possible to the declivity of the dock blocks so that, when docked, it would touch the blocks evenly, and not hinge about either end.

The dock was flooded for the docking of the fore end on May 5, 1942, at 2 o'clock in the afternoon, on a clear, windless, sunny day. The docking was quite normal, except that, in the peculiar circumstances, a locomotive steam crane on one side of the dock was used to draw the portion into the dock. In a short time the fore end was roughly in position, the gates closed and the pumping out of the dock begun. As the pumping proceeded and with the side shores prepared, the fore end was pulled into its final position when just clear of the blocks, with the baulks hard up against the shell and the angle bars on the forward half, and with the mark on the prepared batten coinciding with a chalk line struck on the centre of the stem. As the forward half settled on the blocks, a gap of $\frac{1}{8}$ in. appeared between the upper baulk and the corresponding angle bar on the forward half due to inaccuracy of trimming, causing it to hinge by the after end, with the result that the ship, when completed, was longer by this amount than when originally built.

After the dock had been pumped dry and bilge shores

* Paper read at a meeting of the North-East Coast Institution of Engineers and Shipbuilders, held in Newcastle-on-Tyne on November 14, 1947. Abridged. [The photographs reproduced were supplied by the author, but were not included in the paper. ED. E.]

and blocks placed in position, the position in which the fore end was lying was checked, and it was found to have settled with the correct degree of list and to be in perfect alignment in the vertical plane; but when horizontal sights were taken, it was found that the keel of the forward half was 1¼ in. higher than the keel of the after half. Though this had not been foreseen it was quite understandable, because the aft end, which contained the weight of the main machinery, had been in dock for over a month and had time to settle down, and because the docking had been carried out in conformity with the usual practice of having 3-in. softwood cap pieces on the blocks, and the total weight of the after half with the water added to prevent it floating was much greater than that of the forward half. By running the ballast water out of the forward tanks of the after half and, at the same time, filling the after tanks of the forward half and slackening back the bilge blocks, the two halves came into perfect alignment in about two days, and were then blocked up in position

The two halves now being in the correct position in relation to one another, it only remained to build in the structure between them and connect the pipe lines, electric wiring, etc. During this process, readings of the horizontal sights were taken from time to time, but no movement of the two halves was discernible. No difficulty was experienced in building in the structure between the two halves to complete the ship with perfectly fair lines. The vessel was undocked on June 5, 1942, six weeks after the forward half was docked, and was completed for service ten days later.

The Vardefjell, a sister ship to the Pontfield, was two days out from the Clyde in convoy when she broke in two on December 13, 1942, in heavy weather. The fore end, with all the officers aboard, remained afloat for some hours, but was then lost without trace. For eleven days, until rescued by a fishing vessel, the surviving members of the crew remained on board the after half in wind of hurricane force, with engines going slow astern. The after portion was subsequently recovered by Admiralty salvage tugs and taken to Kirkwall, where it was beached. Here it was prepared for towing and was then brought to the Tyne, arriving at Jarrow Buoys on March 5, 1943, where it lay until May 21, when it was docked for inspection.

As the shipbuilding facilities on the Tyne, were very heavily loaded at this period, it was some time before any decision to repair the ship was reached. Finally, it was decided to proceed with the construction of a new fore end, and a contract to build it was placed with Sir James Laing and Sons, on the Wear. As no detailed specification of the damage in way of the break had been taken when the after half was docked, and as the call on dry docks was very heavy at the time, it was decided to build the new fore half only to the transverse bulkhead forward of No. 6 tank, thus leaving one complete main cargo tank to construct when the two halves were placed in position in dock for joining up. The transverse frames for this new tank were turned by the builders and transported by lorry from Sunderland to Wallsend.

The Vardefjell being a sister ship to the Pontfield, and the break having occurred in roughly the same position amidships, exactly the same general procedure was adopted. Following the experience with the Pontfield, the 3-in. softwood cap pieces were removed from the dock blocks before the after portion was docked, in the hope of eliminating any difficulty in the alignment of the two halves on the horizontal sights. This hope was justified, though, when the dock was pumped dry following the docking of the forward half, the forward end of the after half was found to have sunk 2 in., due to the weight of water ballast (1,000 tons) which was necessary to keep it on the blocks when the dock was flooded. When the ballast was run out, the two halves came into alignment. Arising also out of the experience with the Pontfield, by ballasting the forward half with great care before docking to a trim by the head equivalent to the declivity of the dock blocks, it was possible to put it down on the blocks with the ends of both baulks in contact with the angles, thus making the length between perpendiculars, of the ship as repaired, exactly right.

The Standella, a Diesel-driven tanker of 6,197 tons gross, belonging to the Anglo-Saxon Petroleum Company, was mined in way of Nos. 6, 7 and 8 tanks and was taken into Dakar and dry-docked there for temporary repairs. On examination, the damage was found to be so extensive that it was decided to cut away the three damaged tanks altogether and to insert the fore end of the vessel (consisting of fore peak, deep tank and cofferdam) into what remained of No. 6 tank, which resulted in the flat-plate keel of the fore end being 3½ in. higher than the remainder of the bottom of the vessel. As the two parts of the vessel varied considerably in section where they joined, a streamlined arrangement of welded shell plating was fitted at the join, and in this condition, illustrated in Fig. 8, opposite, the vessel was brought to the Tyne under her own power and dry-docked on July 12, 1945, for permanent repairs.

The repairs consisted of three operations: first, the separation of the two portions of the original ship and the floating of the after portion to its correct position in relation to the forward portion; secondly, the lowering of the aft end of the forward portion to eliminate the 3½ in. discrepancy in the keel line, arising out of the temporary repairs at Dakar; and, thirdly, the rebuilding of Nos. 6, 7 and 8 tanks between the two portions.

While the two portions were being separated prior to floating the after part, horizontal sights were set up in the dock bottom and the fore and aft centre-line of the vessel was projected beyond the stern to a point coinciding with the intended new position of the aft face of the horizontal rudder coupling. As in the previous instances, a batten of suitable length was made. In burning away the connections between the two portions, the streamlined plating fitted in Dakar was left intact on the forward portion, so that its strength and the flat bottom could be used to block up this part, to prevent it settling when filled with water ballast before flooding the dock to float the after portion. In addition, the keel blocks in way of the fore foot were doubled up. This stage of the work is illustrated by the photograph reproduced in Fig. 9, opposite.

As the gap between the two portions, when correctly located, was approximately 56 ft., no arrangement of baulks was practicable and another method of locating was necessary. A 12 in. by 12 in. vertical baulk, the half width of the ship from the sighted centre line, was erected at the port side of the after part of the vessel and secured by bolts grouted into the concrete of the dock bottom, with a horizontal shore to the dock side and flat steel strips with bottle screws on either side, at 45 deg. to the dock side, attached to existing ring bolts in the dock wall (see Figs. 10 and 11, opposite. In addition, a 12 in. bulb-angle stopper, with tripping brackets, was welded to the shell on the strake below the sheer strake at No. 112 bulkhead.

In locating the baulk in relation to the 12 in. stopper on the shell, the baulk was set an additional 1½ in. farther aft to allow for the slight lessening of the distance between the two portions when the fore end was subsequently lowered 3½ in. at the after end—the 1½ in. being the mean of the 2½ in. difference in the distance between the adjacent transverse bulkheads of the two portions at top and bottom. While preparations were being made for floating the two portions apart, calculations were made for the ballasting of the after portion so that it would float, with a trim approximately equivalent to the declivity of the blocks, with a draught less than the 18 ft. at which the fore portion would float with fore peak, deep tank and cofferdam filled. Plumb lines were also hung from the tops of what remained of the port fore and aft bulkheads to check what list, if any, the after portion took when floated.

With all preparations completed, the dock was flooded and the after portion was floated, the draughts afloat being 15 ft. 9 in. forward and 15 ft. 6 in. aft—a trim of 3 in. by the head, whereas a trim of about 12 in. by the stern had been estimated. In view, of the length of the portion, however, it was thought that the effect of this discrepancy in trim would be very slight, and, as time was limited by the tide, it was decided to proceed with the operation. The aft portion was then drawn aft till the vertical baulk was in contact with the shell of the ship and the 12 in. stopper, and, with the mark on the batten coinciding with the centre of the rudder coupling, was docked down.

After the dock had been pumped out, the position of the two portions was checked. It was discovered that the after portion had settled with a list to port of 2 in. on the length of the plumb line, and that it was 3 in. forward of its correct position due to the arrangement of the flat steel strips and bottle screws being insufficiently rigid. Fortunately, there was a buttress in the dock wall at a convenient distance aft of the baulk, and it was possible to fit a shore from this to the baulk at a suitable angle. With this in position and the 12 in. bulb angle refitted 3 in. farther forward, the after portion was refloated the next day. When docked down, it was found to be in its correct position in relation to the fore end, and to have the same 2 in. list to port on the plumb line.

The second operation, the lowering of the after end of the fore part, proved easier than was expected. By slackening away the blocks at the aft end and on the port side, when the ballast had been run out, the keels of the two parts were brought into line in about three hours, and a list to port was given to the fore portion similar to that with which the after portion had settled. With the two portions in their correct position relative to one another, it only remained to build in the missing structure between them. The vessel was undocked on November 13, 1945.

The after half of the Treworlas (then the Harpagus) arrived in the Tyne on December 1, 1944, the fore half having been lost following two underwater explosions while approaching the Mulberry Harbour at Arromanches Beach. The ship, which had four holds and a deep tank forward of the engine-room, had broken in two just forward of the deep-tank bulkhead, which was the after bulkhead of No. 2 hold or No. 92 bulkhead.

The after half was docked for inspection and to obtain the necessary data for the builders to construct the new forward half. Fig. 3, on page 60, shows the after part of the vessel in dock on May 4, 1946. It was found to have extensive bottom damage caused by beaching to unload cargo. After undocking, the after half was placed at buoys while the new forward half was built at the Walker Yard of the Shipbuilding Corporation, Limited. Although No. 92 bulkhead was not damaged beyond repair, it was necessary, for the sake of buoyancy, to include it in the construction of the new forward half. While the after half was at the buoys, 700 tons of sand ballast were removed from No. 3 hold, leaving the after half trimmed 2 ft. 3 in. by the stern with a draught of 13 ft. 3 in. aft, which was satisfactory for docking. The after half was redocked stern first on May 2, 1946, and settled with a list to port of 2 in. on a plumb line 24 ft. long.

The same arrangement of baulks and methods of sighting were employed as in the cases of the Pontfield and Vardefjell. To destroy the buoyancy of the after half for the docking of the new fore half, one strake of plating, port and starboard, already damaged and specified for renewal or to be removed, faired and refitted, was removed, and, before the dock was re-flooded, the manhole covers in the holds were also removed. Calculations showed that, in this condition, this half would lift with 17 ft. 6 in. of water over the blocks, and, as the water over the blocks at high tide would exceed this, it was arranged, in view of the possibility of a hitch occurring during the docking of the forward half, to dock it on an ebb tide so that delay would not result in the aft half floating.

The forward half was launched on May 16, 1946, and floated at 5 ft. 1 in. aft and 10 ft. 6 in. forward, a trim by the head of 5 ft. 5 in. As the trim required on the length of this portion to coincide with the declivity of the blocks was 6 in., it was necessary to weld up No. 115 floor and fill the double-bottom tank between Nos. 103-115 frames, giving 130 tons of ballast; and to put 100 tons of pig-iron ballast at the after end of No. 2 hold, this latter ballast being also arranged to give a list to port of 2 in. in 24 ft. assumed by the after half on docking. With this ballast in position, the draughts were 8 ft. 8 in. aft and 9 ft. 2 in. forward, giving the required 6 in. trim by the head.

The docking of the forward half, illustrated in Fig. 4, on page 60, took place on May 24, 1946. The dock was first flooded slowly up to 10 ft. above the blocks on the flood tide to allow time for Nos. 3 and 4 holds to flood. The sluices were then closed. They were re-opened on the ebb tide and the dock was flooded up to river level. The gates were opened with a draught of 15 ft. over the blocks. As soon as the forward half was in the dock, the gates were closed and the dock pumped down to 10 ft. above the blocks; the fore half was then pulled into position and docked down. Subsequent checking of sights showed that both halves of the vessel were about ¾ in. down at the break, but, after removal of the ballast, a satisfactory alignment was obtained, and the work of building in the structure between the two halves begun. The vessel was undocked on July 24, 1946, and delivered to the owners on September 14.

The Giert Torgersen (then the Thorshovdi) was badly damaged in way of Nos. 5, 6 and 7 main-cargo tanks by limpet mines, fixed underwater by Italians while the ship was lying at Gibraltar. The ship remained afloat, however, and was subsequently dry-docked, when No. 6 tank was cut away and the two separate halves undocked. The two halves arrived in the Tyne on May 27 and July 7, 1946, where they lay until they could be taken in hand for repair.

The forward half of the vessel included the after bulkhead of No. 5 main cargo tank, which also formed the aft end of No. 3 wing tanks, and, this bulkhead being damaged, these tanks were open to the sea. In addition, No. 4 centre and the fore deep tank were full and No. 2 port and starboard tanks had a 10 ft. 0 in. sounding to give a more or less level trim. The after half of the vessel was complete from aft to forward bulkhead of No. 7 centre tank and No. 4 port and starboard wing tanks, which had been made watertight by temporary repairs at the previous docking. To balance the weight of the engines, No. 7 and No. 4 port and starboard tanks were full, No. 8 centre tank contained 22 ft. 0 in. of water, and No. 5 port and starboard 13 ft. 8 in. and 16 ft. 0 in., respectively; No. 9 tank contained 1 ft. 0 in. of water. This ballasting gave the forward portion a draught of 13 ft. 4 in. and the after portion a draught of 19 ft. 10 in. forward and 20 ft. 6 in. aft.

In view of the heavy draught of the after end, and, as the tidal prediction on the docking date gave a maximum depth of water over the dock sill of 22 ft. 6 in., it was decided to dock the two halves at the same time. The fore end was to enter the dock first, followed by the after end, which was to be docked down as nearly as possible centrally on the blocks. The fore end was

WAR-TIME SHIP REPAIRS.

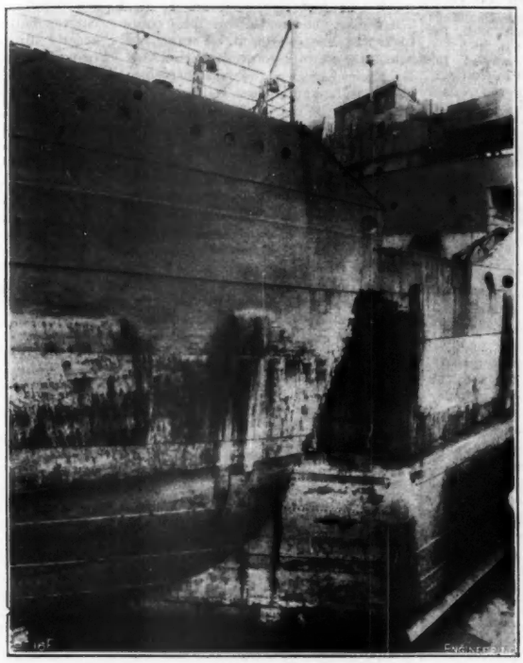


FIG. 8. TEMPORARY JOIN IN M.V. "STANDELLA."

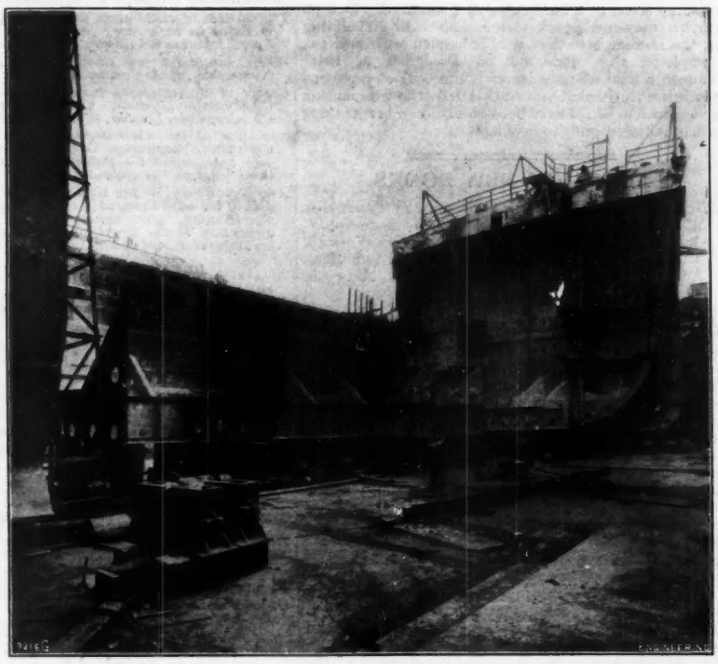
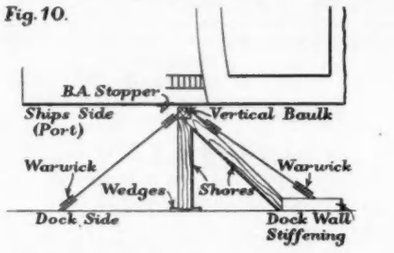
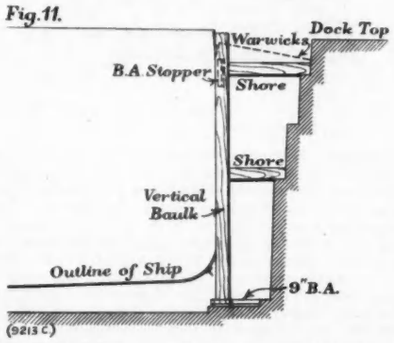
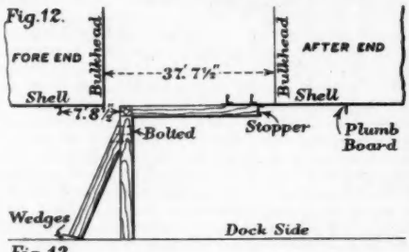
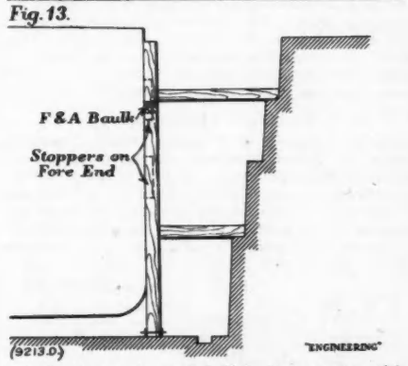


FIG. 9. REBUILDING DAMAGED TANKS, M.V. "STANDELLA."









then to be docked down slightly forward of its correct relative position, into which it was to be subsequently refloated after the necessary preparations had been made. The docking took place on July 26, 1946, and is illustrated in Fig. 1, on page 60. The after end was docked centrally on the blocks by using the guide wires normally employed to centre the after end, in conjunction with an accurately-cut shore on the port side between the dock altar and the shell in way of the forward bulkhead of No. 4 port wing tank. With the after end in position, the fore end was then placed on the blocks, the dock pumped out and bilge blocks and shores fitted under both ends. Fig. 2, on page 60, shows the gap between the two halves at this stage of the work. With the dock pumped dry, a check was made on the position of the after end, with vertical and horizontal sights, and a plumb line on board attached to the shell on the port side. It was found to be lying centrally on the blocks with a list to port equivalent to 1¼ in. on the length of the plumb line, which was 22 ft., or roughly half a degree.

To locate the forward half in its correct position when refloated, the same method was adopted as in the case of the Standella, namely, a vertical baulk was secured to the dock bottom and shored to the dock side with, in this case, a horizontal timber bolted through the frames to the shell on the after end (Figs. 12 and 13). The correct position for the shore was found by projecting the centre line of keel of the after end forward and taking the half width of ship to outside of shell to the inboard face of the baulk, plus an additional allowance at the top to correspond to the 1¼ in. list of the after end. A bulb-angle stopper was fitted on the sheer strake on the port side of the forward half, to engage with the baulk when the two halves were the correct distance apart.

To obtain a correct alignment of the two halves in the fore and aft vertical plane, sights were erected at the head of the dock on the projected centre-line of the after half, and a chalk line struck down the centre of the stem. In addition, a wire secured to the blocks on the projected centre-line was stretched to the centre of the top of the stem, so that, when the fore end was floated and ballast added to give a similar list to port as that of the after end, with the sights, chalk line and wire in line, the stem would be in its correct position in the fore and aft vertical plane.

As the two ends were docked on the day before the commencement of the works' holiday week, preparations for the refloating of the fore end were not completed until August 11, 1946. The first attempt was made on the following day; this proved unsuccessful, as the vessel persisted in listing to starboard when still a few inches clear of the blocks. After three attempts had produced the same result, the operation was abandoned for the day and the dock pumped dry. On inspection, it was found that a bottom shore, from the after half, had broken adrift when the dock was flooded and lodged on top of one keel block on the port side; fortunately, without doing any damage to the structure. It was assumed that this was the cause of the vessel's listing to starboard, and, after the shore had been removed, the dock was flooded again the next day, this time with the bottom shores under the after end roped. Two more attempts were made to locate the forward end with, however, the same result as before. It could only be assumed that this listing was caused by the free-surface water in No. 2 port and starboard tanks; so, at the third attempt, the cross-over valve between these two tanks was opened, and the fore end lowered on to the blocks. This at last proved successful, and it settled with the required list to port.

On checking the vertical sights on the keel, the two halves were found to be in line, but, when readings were taken on the horizontal keel sights, it was found that the fore end of the after half was 2½ in. down. This was, no doubt, due to the fact that, though well blocked up, it had lain in the dock heavily ballasted for 17 days before the refloating of the fore end. Had this been foreseen, it might have been avoided by emptying the tanks after docking and refilling when the fore end was ready for refloating, though sightings which were taken on the dock blocks, designed to measure the compression of the blocks under the weight of the ship, lead the author to think that this discrepancy, which was larger than any previously experienced, was in part due to subsidence of the dock bottom. So great was the discrepancy that consideration was given to the advisability of undocking both ends, and starting again with the declivity of the blocks in way of the after end slightly increased. In view, however, of the urgent desire of the owners to avoid delay and get the ship into service, it was decided to attempt to bring the two halves into line by ballasting while the scrap steel on both ends in way of the break was being removed.

By the next day, with all ballast run out of the aft end,

the discrepancy was reduced to 2 in., and, 12 days later, with the double-bottom tanks in way of the engine-room and the aft peak full, it was reduced to $\frac{1}{4}$ in. Thereafter, it was reduced very slowly by the removal of scrap steel, to a final figure of $\frac{1}{4}$ in., after which no further movement took place. The work of building in the missing structure was proceeded with and the completed ship undocked on December 4, 1946. Though a final discrepancy of $\frac{1}{4}$ in. does not represent perfection, it should be noted that deflections amounting to as much as $4\frac{1}{2}$ in. have been observed on new tankers when ballasted prior to docking.

NOTES ON NEW BOOKS.

Mechanical Vibrations. Third edition. By PROFESSOR J. P. DEN HARTOG. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 6 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 30*s.*]

THE publication of a new edition of a technical book is usually an indication of merit and an occasion for the author to increase the practical value of the work by extending the application of the theory to those branches in which advance has been made in recent years. The present instance is a case in point, for the excellent exposition of the principles of the subject which the previous edition contained has been brought up to date by the inclusion of information on problems which experience, during the past decade, has shown to be of increasing importance. By embodying the new matter into the earlier text, Professor den Hartog has elucidated several instructive applications of the elementary theory, such, for example, as torsional pendulum dampers, helicopter ground vibration, "singing" propellers, wing flutter, and electronic instruments. With the present congestion of universities and technical colleges in this country, there must be many young engineers who are unable to attend courses of study and who feel the need of guidance on the path leading to the associate-membership of the senior institutions. In view of these circumstances and the numerous ramifications of vibration theory, it may be remarked that the book can be followed by the serious student without the aid of an instructor, owing to the relatively light mathematical equipment required for a thorough grasp of the essential points and to the potential value of 131 exercises with answers which have been placed at appropriate places in the text. Lecturers on the subject will find a store of useful data in this volume; and the extended list of sources of references for further study will be welcomed by both classes of reader.

Manual of Mathematics and Mechanics. By PROFESSORS G. R. CLEMENTS and L. T. WILSON. Second edition. McGraw-Hill Book Company Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 3·25 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 16*s.* 6*d.*]

THIS book, first published in 1937 and now revised, contains mathematical tables and a comprehensive summary of important facts and formulæ relating to mathematics, mechanics and certain branches of applied physics. It serves to show students who have attended courses of study in these subjects the extent of the work they may be expected to understand and is also suitable for reference purposes or practical application. The 24 mathematical tables take up nearly one third of the book. These are mainly of four-figure accuracy and include, in addition to the usual logarithmic and trigonometric data, values of exponential and hyperbolic functions, inverse trigonometric and hyperbolic functions, elliptic integrals, and other numerical data of a useful character. The mathematical summary adequately covers all the most important points in connection with algebra; plane and spherical trigonometry, plane and solid analytic geometry, the differential and integral calculus and other topics of mathematical interest. The long list of integration formulæ is a noteworthy feature, but it is curious that this should come at the beginning of the mathematics section and not in that portion dealing with the calculus. The mechanics section summarises fundamental principles and formulæ and other sections deal similarly with strength of materials, continuous and alternating current work and fundamental radio circuits. An alphabetically arranged glossary has been added, in which a number of technicalities in modern heat, light and sound are concisely explained. The mathematical section should be useful to students and others who already possess a good knowledge of mathematics and who seek either to refresh their memories or to apply the information for some practical purpose. It is questionable, however, whether a student wishing to look up information on the engineering applications of mathematics would not do better to consult a text-book of the standard type.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

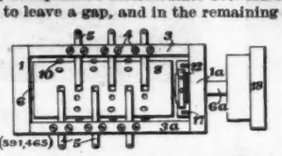
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

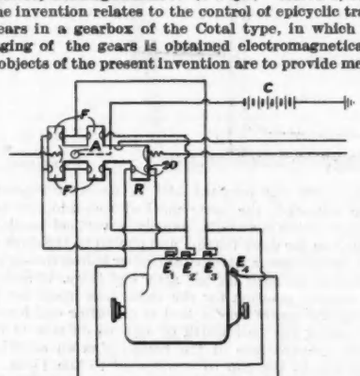
591,465. Rotary Multiple Switch. Muirhead and Company, Limited, of Beckenham, Kent, and W. C. Lister, of Beckenham, Kent. (5 *Figs.*) November 17, 1944.—The invention is a switch enabling one or more of a relatively large number of circuits to be completed, and interrupted or interconnected at will without the necessity for the use of long leads, a matter of particular importance in high-frequency electrical apparatus. Two end plates 1, 1*a* are connected together to form a frame by two side pieces, to which are secured by fillets 3 and 3*a* and bolts 4 a number of spring contact blades 5. These blades extend in a direction tangential to the surface of the rotatable portion of the switch. Two trunnions 6 and 6*a* are secured in plugs engaged in the ends of a length of tubing 8, which forms the major part of the rotatable member. A portion of the wall of the tube, at a position intermediate between its ends, is removed to leave a gap, and in the remaining portion



of the wall of the tube are placed contact studs 10 having shanks extending beyond the inner surface of the wall of the tube so that permanent electrical connection between selected studs may be made by wires soldered or similarly secured to the shanks. On the trunnion 6*a* a collar 12 is fixed, which is furnished at intervals with grooves, and on the adjacent end of the frame is secured a spring in which there is a hole carrying a spring-loaded ball, which engages with one or other of the grooves to retain the rotatable member in positions in which the spring contacts are in register with the studs. Stops are provided on the frame to limit the movement of the rotatable portion of the switch. A knob 18 is fitted to the trunnion to operate the switch. With this switch construction, for each position of the switch the connections established may be completely independent of the connections established when the switch is in any other position. (*Sealed.*)

MOTOR VEHICLES.

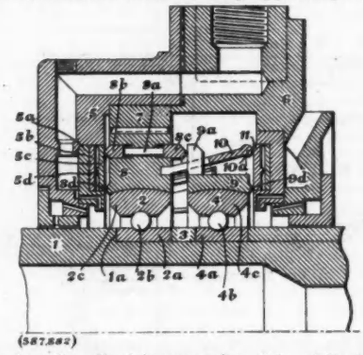
591,153. Control of Epicyclic Gears. Lagonda, Limited, of Staines, Middlesex, and W. O. Bentley, of Colnbrook, Buckinghamshire. (5 *Figs.*) March 5, 1945.—The invention relates to the control of epicyclic trains of gears in a gearbox of the Cotal type, in which the engaging of the gears is obtained electromagnetically. The objects of the present invention are to provide means



whereby simultaneous engagement of the reverse gear with a low gear in the gearbox is prevented, and alternate forward and reverse movements can be obtained by movement of a single lever only. The gear lever A can be moved to any one of four forward gear positions F and to reverse gear position R, which cause the energisation of the appropriate solenoids connected to terminals E_1, E_2, E_3, E_4, for selection of the required gear train as in any standard Cotal-type box. The current is supplied by the battery C. Selection of the required gear ratio in forward drive is carried out as follows:—First gear: the circuits containing contacts corresponding to E_3 E_2 are energised. Second gear: the circuits containing contacts corresponding to E_3, E_4 are energised. Third gear: the circuits containing contacts corresponding to E_1, E_2 are energised. Fourth gear: usually direct gear, the circuits containing contacts corresponding to E_1, E_4 are energised. Reverse drive is obtained by means of an independent epicyclic gear train (not shown), which may be operated either by mechanical means or by another solenoid. If the reverse gear were to be used in conjunction with the first or second gear in the gearbox proper, the combined reduction would be such as to put excessive torques on the transmission, with consequent damage to certain parts. To prevent this possibility, movement of the gear lever A to the reverse position R is arranged to energise a predetermined gear, which may be third gear, as shown, this being the gear required in conjunction with the reverse-gear train to give the desired overall gear ratio in reverse drive. For this purpose, in the reverse position in the gate two contacts 20 are provided so that, on movement of the shift lever A to the reverse position in the gate, the circuits to the solenoids E_1, E_2 are energised, thereby causing third gear to be selected whenever in reverse. (*Sealed.*)

MISCELLANEOUS.

587,882. Double Ball Thrust Bearing. Power Jets Limited (In Liquidation), of Whetstone, Leicestershire, and R. C. McLeod, of Whetstone, Leicestershire. (1 *Fig.*) June 10, 1943.—This invention relates to a ball bearing capable of taking axial thrust loads as well as journal loads. Ball bearings can be made to deal satisfactorily with axial thrust loads, but in some cases this is not practicable. The invention affords means whereby multiple rows of balls may be used as thrust bearings, the rows sharing the duty. A hollow shaft 1 has a step formed externally at 1*a*, against which abuts the inner race 2*a* of a bearing assembly which has balls 2*b* and outer race 2*c*. Fitting on the shaft 1 behind the race 2*a* is a spacing collar 3, and the inner race 4*a* of a second bearing assembly which has balls 4*b* and outer race 4*c*. Surrounding the shaft and bearing arrangements is a bearing housing 5, 6, forming part of the structure of the machine as a whole. Within the housing 5 an internally-splined ring 7 is secured and this carries a bearing support ring 8 which



is externally splined to engage 7, and is axially drilled with a series of circular holes in which slide rods 8*a*. The holes interconnect channels on both flanks of the support ring 8, and in these channels lie rings 8*b*, 8*c*, the interior edges of which bear on the ends of the rods 8*a*. The interior of the support ring 8 is formed with partly spherical contour, to correspond with the spherically-formed outer surface of the track 2*c*. The support ring 8 also has a series of ribs 8*d*, formed on one flank. The outer projecting edges of the rings 8*b*, 8*c*, and the ribs 8*d*, are formed with rounded noses to afford as nearly as possible line contact. The housing 5, through an inset annular part 5*a*, supports a hard-steel ring 5*b*, in a recess, and loosely mounted also therein is a series of rocking plates 5*c* with bearing-ribs 5*d*, which bear on the ring 5*b* so that each plate 5*c* can rock. The ring 8*b* bears on the plates 5*c* to one side of rib 5*d*, and the rib 8*d* to the other side, so that a plate 5*c* acts as a rocker on the pivot formed by 5*d*. Bearing 4 is also spherically mounted in a ribbed support ring. The support ring 9 of bearing 4 has radially extending lugs 9*a*, which bear against the ring 8*c* of bearing 2, and has a series of ribs 9*d* corresponding to the rib 8*d* above mentioned. Located by a groove in the flank of support ring 8, is a frustro-conical hoop 10, which is cut away to pass the lugs 9*a*, and which extends outside bearing 4, having at its rear edge a line-contact nose formation 10*a*, to bear on rocker plates 11 against which the rib 9*d* also bears. The plates 11 are supported by the housing 6 so that they can rock. Bearing 2 is operative, normally as a journal bearing; bearing 4 has no radial support capable of taking any appreciable load. The thrust load is shared between the two bearings. (*Sealed.*)